FUNDAMENTALS OF ZOOLOGY

(FOR FIRST YEAR SCIENCE STUDENTS)

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FOREWORD

The book, by two of my old students, is a welcome addition to text books in Animal Biology for the Frst Year College Course. Behind its preparation is mature experience of several years. It is not a rehash of old material but is a fairly comprehensive survey of animals and their life processes.

An animal is a dynamic organism. To beginning students nothing is fascinating than an insight into how organisms—particularly human beings—function. To appreciate and understand how an animal functions, an acquaintance with the physico-chemical facets of life is necessary. The authors are to be congratulated on keeping this perspective in mind and on judiciously stressing only such essentials as are required for an understanding of the principles with reference to structure and function. I wish the book all success.

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PREFACE

This book is intended to give a bird's-eye view of the fundamentals of zoology to First Year Science students. It has been prepared with care and in conformity with the syllabus of the University of Bombay as modified by the Board of Studies in Zoology, and may be profitably used by pre-University students of the other Universities as well. In view of the somewhat inadequate knowledge of English which a majority of our students possess nowadays, the manner of presentation has been simplified, and the language used is simple, direct and uncomplicated.

To Dr. N. N. Murti, Principal of Jhunjhunwala college, we are deeply beholden not only for the Foreword which he has very kindly written but also for his encouragement and valuable guidance. Our sincere thanks are also due to Mr. S. V. Kadhe, Mr. M. P. Dawalkar, Mr. P. D. Deodhar and Mr. R. T. Laul who, at considerable personal inconvenience, went through parts of the typescript and offered valuable suggestions.

We are indebted to Dr. P. T. Muthe and Prof. R. M. Pai for their guidance during the revision of our 2nd Edition.

P. M. Rao
R. D. Chawathe

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Introduction

1

Life on this Earth is represented by plants and animals. The science that deals with the study of life or of living objects is known as *Biology* (*Bios*=life, *logos*=discourse or science). Thus, Biology as a subject includes the study of both plants and animals. The branch of Biology that covers the study of plants is known as *Botany* (*Botane*=herb), while the branch that deals with the study of animals is termed as *Zoology* (*Zoon*=animal).

Biology can be studied from two aspects: (1) Pure; and (2) Applied.

1. **Pure Biology.** It includes the study of living organisms as they occur in nature.

2. **Applied Biology.** It is the application of the study of biology to the welfare of the mankind.

SUBDIVISIONS OF PURE BIOLOGY

Organisms Studied as Individuals

Morphology. It covers the study of forms and structures of organisms. It is subdivided into:

(a) **Anatomy,** the study of internal gross structure;
(b) **Histology,** the study of tissues; and
(c) **Cytology,** the study of cells.

Physiology. It deals with the various functions of organisms or their different parts.

Embryology. It comprises a study of the development of an organism from the fertilized egg.

Organisms Studied in Group Relations

Taxonomy or Systematic Biology. It includes the classification of animals and plants based on various morphological and physiological peculiarities.

Ecology. It is a study which reveals the relationship of individuals to their environment. The geographical distribution of plants is known as *Phytogeography*, whereas that of animals is known as *Zoogeography*.

Genetics. It covers the study of animals and plants in relation to inheritance and problems concerning heredity.

Organic evolution. It is the term applied to process of the progressive changes which leads to the formation of complex organisms from the simpler ones.

SUBDIVISIONS OF APPLIED ZOOLOGY

Fisheries. It deals with the biological study of aquatic animals particularly the fishes, crayfishes and mussels, and its useful application in supplementing the food resources of man. In short, it is "marine farming".

Husbandry. It is that specialised branch of veterinary science whose main object is to improve the stock of cattle and poultry, both qualitatively and quantitatively.

Medicine. It is the science of prime importance to man, which helps in curing and eradicating the diseases and ailments of mankind.

Hygiene. It is the science which embodies the laws of good health.

Eugenics. It is the application of genetics to man, plants and animals for producing a better and vigorous progeny.

BIOLOGICAL WORDS

Anatomy
Cytology
Ecology
Embryology
Genetics
Husbandry
Taxonomy

QUESTIONS

1. What is the importance of the study of Biology?
2. Fill in the blanks to make the statements true:—
   (i) Study or functions of organs is called as...........
   (ii) Cytology is the study of......
   (iii) Study of individuals in relation to their surrounding is called as..
   (iv) The study concerning heredity is known as.........

Cell

2

The word cell is used in biology to indicate the structural and functional unit of life which builds the living organisms.

The word cell was first used by Robert Hook in 1665 to explain the empty honeycomb-like chambers or compartments that he observed in a section of cork under the microscope.

A living cell, irrespective of its shape, consists of a viscous fluid called *Protoplasm*, and was referred by Huxley as the "physical basis of life." The protoplasm can be differentiated into *cytoplasm*, and *Nucleus*.

Thus the cell is a mass of cytoplasm bounded by a delicate elastic membrane and containing a nucleus.

The cytoplasm and the nucleus together constitute the protoplasm. Since the protoplasm is the basis of life activities, in the absence of either its nucleus or cytoplasm, the cell ceases to be functional.

The plant or animal body is made up of cells. In certain simpler organisms like the amoeba, bacteria or spirogyra, the body is either made up of a single cell or only a few cells. In others, the body is made up of numerous cells. Therefore, the animals are either unicellular or multicellular. Thus the cells are the structural units of living organism. In a unicellular organism like the amoeba, the single cell performs all its vital functions. In multicellular organisms, similar cells are organised into tissues, organs and systems. The physiology of a multicellular organism amounts to the sum total of the functions of its various tissues, organs and systems. The cell, therefore, is not merely a structural unit, but also a functional unit, for it carries on processes like nutrition, respiration, excretion, reproduction, etc.

A Typical Animal Cell

A typical animal cell (Fig. 1) consists of the following parts :

(1) **Cell membrane** (Plasma membrane). Every cell has a limiting thin membrane which is formed by the condensation of the outermost peripheral region of cytoplasm. This is semipermeable. A rigid cell-wall outside this cell membrane is found only in plant cells, and is rarely present in animal cells.

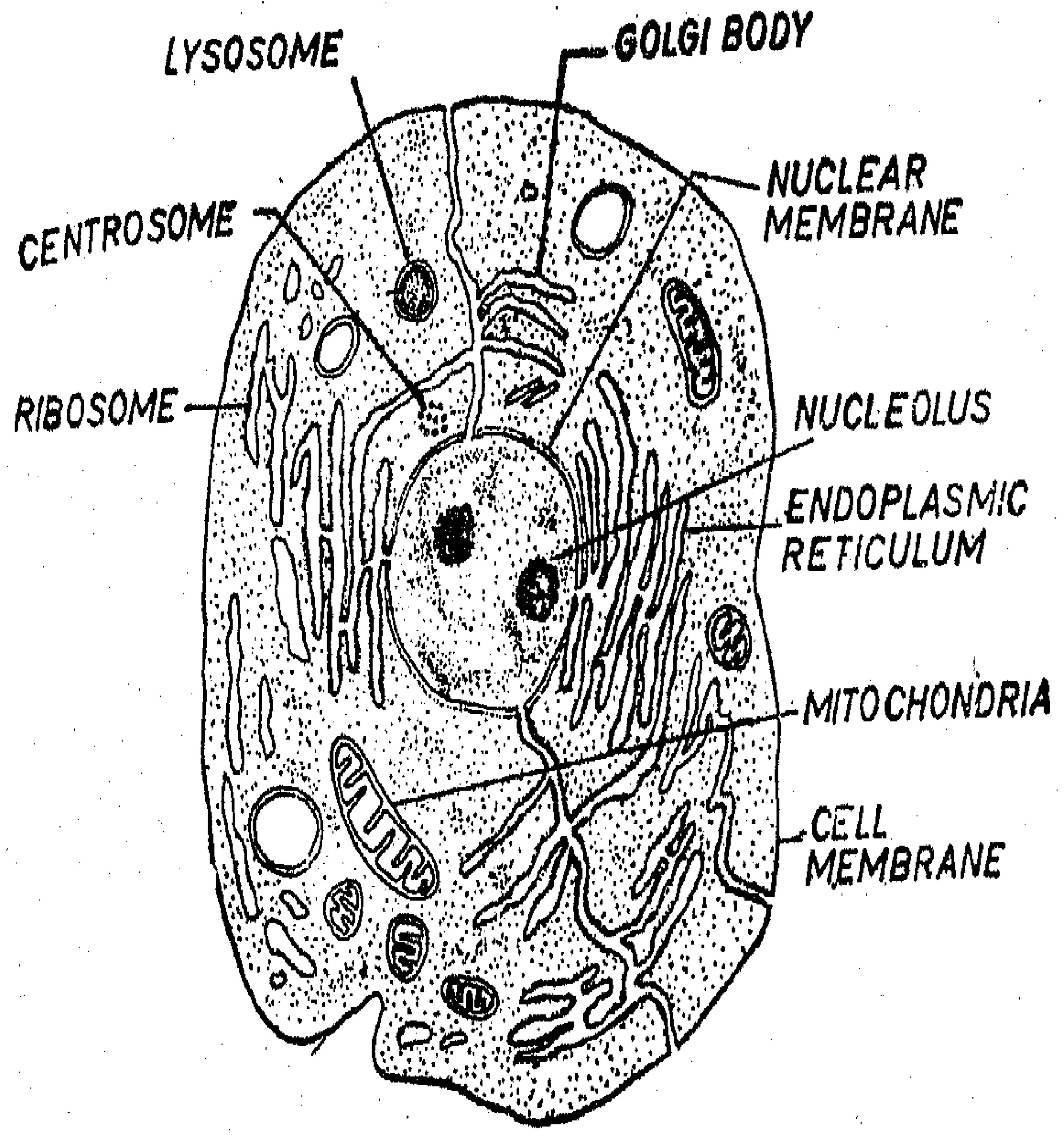


Fig. 1. *A typical Animal Cell*

(2) **Nucleus.** With rare exceptions, all cells have an organised spherical body of protoplasm lying in the cell called the nucleus. It has its own thin semipermeable membrane, the *nuclear membrane*, enclosing a specialised mass of protoplasmic substance known as *nucleoplasm* or "nuclear sap" or "karyo-lymph". One or more spherical particles, the *Nucleoli* (singular, *nucleolus*), are generally seen in it. The nuclear membrane, under an electron microscope, appears to consist of two layers, of which the outer layer is porous. Through the pores, the cytoplasm and the nucleoplasm are said to be in intimate diffusible association with each other. Suspended in the nucleoplasm is a network of fine thread-like structures made up of granular filaments of *Chromatin*. This becomes stained and visible after fixation and staining with certain dyes. Chromatin is chiefly Nucleoprotein, containing mainly the Desoxyribose nucleic acid (DNA) and also Ribose nucleic acid (RNA), which is localised in the nucleoli During nuclear division, the chromatin becomes condensed into characteristic structures, the *Chromosomes*. The numbers and kinds of the chromosomes are always the same in all the body cells of an organism. The chromosomes are referred to as the bearers of hereditary characters.

(3) **Cytoplasm.** The cytoplasm is that part of the cell which lies outside the nucleus. It is a viscous fluid with a number of bodies suspended in it. A central body or *Centrosome*, which is star-shaped, lies in the cytoplasm just outside the nucleus. This contains either one or two granules, the *Centrioles*, which are the division centres. The centrosome plays an important role in the process of cell division. Centrosome is present mostly in animals and only in lower plants. Granules of small size and of various shapes (rods, threads, or granules) are seen embedded in the cytoplasm and are called *Mitochondria*. They are centres of enzyme activity in cellular respiration. Another structure, in the form of network, found in the cytoplasm is called *Golgi body*, whose function is not fully understood. It is suggested that the golgi body or golgi apparatus is concerned with the secretory activities of the cell.

The other cytoplasmic structures, which may or may not be found in a cell, include vacuoles and plastids A vacuole is usually a cavity that contains a fluid known as cell sap. They are more prevalent in plant cells than in animal cells. The plastids are especially characteristic of plant cells. They may be colourless, but often contain plant pigments, which give colour to the different parts of the plant.

In addition, the cytoplasm may contain a variety of inclusions which are the metabolic products of the cell.

Differences Between a Plant cell and an Animal cell

Plant Cell	*Animal Cell*
(1) A rigid cell-wall outside the cell membrane made up of non-living material, the cellulose.	(1) Only cell membrane present.

Plant Cell	*Animal Cell*
(2) Plastids of different types present.	(2) No plastids.
(3) Centrosome absent except in some lower forms like algae and fungi.	(3) Centrosome present.
(4) Vacuoles are more typical in plant cells and widely present.	(4) Vacuoles are not so prevalent.

SUMMARY

1. A cell is the unit of life.
2. Protoplasm is the 'physical basis of life' which is differentiated into Cytoplasm and nucleus.
3. Nucleus controls all the activities of cell.
4. The nucleus is bounded by a nuclear membrane and contains nucleoplasm.
5. Chromosomes which are the bearers of hereditary characters are present in the nucleus.
6. Centrosome, a star-shaped body is found in animal cells. It lies outside the nucleus.
7. Golgi body is concerned with the secretory activities.

BIOLOGICAL WORDS

Protpolast
Nucleus
Nucleolus
Centrosome
Golgi body
Chromosome
DNA
RNA

QUESTIONS

1. Describe the structure of an animal cell. How does it differ from plant cell?
2. Write short notes on:—
   (a) Nucleus, (b) Mitochondria, (c) Chromosomes.
3. Fill in the blanks with appropriate words.
   (i) Chromosomes are concerned with ———(Heredity, Attracting the insects for pollination.
   (ii) Nucleolus contains———(DNA; RNA).
   (iii) Mitochondria are mainly concerned with—(Digestion Respiration, Excretion).

Protoplasm

3

Protoplasm is a complex dynamic mixture of organic and inorganic compounds. Its composition is constantly changing with the metabolic state of the cell. The true nature of the protoplasm is difficult to obtain, for it gets killed when it is treated with chemicals used during analysis.

Characteristics of Protoplasm

The protoplasm shows some physical and chemical properties. Besides, the protoplasm has its own biological characteristics.

Physical properties. It is very difficult to understand the structure of the protoplasm. Under the ordinary microscope, it appears as homogeneous matter. Under the electron microscope, it presents a homogeneous matrix (ground substance), in which, is found a system of network of membranes (endoreticulum). The protoplasm is a viscous liquid in colloidal state. A colloidal solution is a system of suspended particles (in a medium), which are in a ma-cromolecular state. Like many colloids, the protoplasm has the capacity to change from a watery, semi-fluid condition to a jelly-like semi-solid condition; or, in a similar fashion, from a "gel" condition to a "sol" condition. One of the important properties of living protoplasm, is its ability to form a membrane at its surface.

Chemical properties. The energy necessary for the maintenance, growth and all other activities of the protoplasm is derived from the interactions of the various chemical constituents present in it. A large number of elements occurs in the protoplasm. No element is unique in living matter. The most abundant elements are hydrogen, carbon, nitrogen, oxygen and phosphorus. They constitute about 99% of the whole mass of protoplasm. Other elements usually present, but less abundant, are sodium, chlorine, potassium, calcium, magnesium, iron, copper, cobalt, zinc, manganese and iodine. These together constitute 1%.

These elements, except the oxygen, are not found in a free state but in the form of various compounds both organic and inorganic.

The organic compounds are the carbohydrates, fats and proteins. The inorganic compounds are water and salts.

Carbohydrates. These are the sugars, and their condensation gives rise to carbohydrates. These are compounds of carbon, hydrogen and oxygen, in which hydrogen and oxygen are present in the same proportion as in water. The simplest type of carbohydrate is glucose ($C_6 H_{12} O_6$). The complex type of carbohydrate is starch ($(C_6 H_{16} O_5)n$). Carbohydrates are the fuel foods which, on oxidation, release the necessary energy for day-to-day activities. Thus, carbohydrates are the source of energy for protoplasmic activities.

Fats. They are compounds of a molecule of glycerol and three molecules of fatty acids. They contain carbon, hydrogen and oxygen. The amount of oxygen is less than that which is present in carbohydrates. Like carbohydrates, they are also fuel foods which, after oxidation, release energy. The presence of less oxygen makes them take up more oxygen during oxidation; and therefore they release more energy than carbohydrates do. Normal fats are oils, lecithin, cholesterol, etc.

Proteins. Proteins are the main constituents of protoplasm, and are compounds of carbon, hydrogen, oxygen and nitrogen. Because of the presence of nitrogen, they are called nitrogenous compounds. The structural unit of protein is amino acid. It is the linking up of many such amino-acids which builds up complex proteins. Proteins combine with other compounds to from other important constituents of living matter. These conjugated proteins are, in many cases, more important than pure proteins; *e.g.*, Nucleoprotein, Albumin, Globulin.

Inorganic compounds. Water is the most abundant and essential constituent of protoplasm, and it amounts to 60% to 90%. The inorganic compounds that occur commonly in the protoplasm are the chlorides, carbonates, phosphates and sulphates of sodium (Na), potassium (K), calcium (Ca), magnesium (Mg) and iron (Fe). For normal functioning of protoplasm, these are quite necessary in definite proportions.

There are also certain important atmospheric gases like oxygen and carbon dioxide present in a dissolved state in the protoplasm.

Biological properties. Certain vital properties are exhibited by living organisms. These are the end results of chemical and physical relationships, too complex to be explained in the absence of certain scientific data.

The protoplasm exhibits the following properties :

1. **Metabolism.** Certain chemical activities are going on inside the protoplasm, some of which are constructive, while others are destructive in nature. All these activities together are called **"metabolism."**

Metabolism includes two phases—*anabolism*, which includes the synthetic processes by which simple substances are changed into complex materials of protoplasm (assimilation), and *catabolism*, which includes the breaking-down of complex substances into simpler ones, liberating energy and yielding waste (disintegration). Anabolism results in storage of energy and in *growth*; catabolism releases the energy for heat, movement, and chemical analysis in the body.

2. **Reproduction.** The protoplasm has the capacity to divide and produce new units of the same kind. This process of reproduction is attained when the mass of protoplasm has reached a certain stage of growth. The resulting units of division are alike, both qualitatively and quantitatively.

3. **Irritability.** The protoplasm responds to different stimuli, both external and internal. Different normal stimuli are provided by light, change in temperature, pressure, sound, etc. The protoplasm is capable of conducting an impulse, caused by such a stimulus, from one part of its mass to another.

SUMMARY

1. Protoplasm is a complex mixture of organic and inorganic compounds.
2. It shows physical and chemical properties.
3. The cytoplasm contains organic compounds like carbohydrates, fats and proteins.
4. Protoplasm shows properties like metabolism, reproduction and irritability.

BIOLOGICAL WORDS

Protoplasm
Carbohydrate
Protein
Metabolism
Irritability
Reproduction

QUESTIONS

1. Give an account of Protoplasm.
2. Fill in the blanks.
    (i) Proteins are made up of Carbon, Hydrogen, Oxygen and also....
    (ii) In Carbohydrates ratio of H : O is..............

Tissues, Organs and Systems

4

In a unicellular organism like an amoeba, one cell performs all the vital functions of its body. There is no special division of its protoplasm into many cells as in a multicellular organism.

Either as a single cell or as a group of cells, the individual organism behaves as a unit. It has organisation. However, in multicellular individuals, all the cells do not carry on all the functions of the body. There is a division of labour. Groups of cells get differentiated and specialised to perform particular functions. Each specialised group of cells gets bound together to form a *tissue*. Thus a tissue may be defined as a group of cells having the same structure and function.

Typical animal tissues are: (1) Epithelium; (2) Connective tissue; (3) Muscular tissue; and (4) Nervous tissue.

Organs. When a number of tissues, however diversified in structure, are brought together to perform some definite and limited functions, they form an *organ*. Thus an organ, like the heart which is concerned with circulation, is formed of varied tissues such as muscular tissue, epithelium, connective tissue and nervous tissue.

Systems. Two or more organs, even when they differ from each other in structure, are grouped together for an ultimate common function. Such an assemblage of organs is called a *system*. Thus various systems—such as digestive, circulatory, respiratory, excretory, reproductive, nervous, skeletal and muscular—have come to form a multicellular individual, each performing a specialised function of the body.

FUNDAMENTAL ANIMAL TISSUES

There are four major types of animal tissues:

(1) Epithelial or covering tissue;

(2) Connective or supporting tissue, including blood;

(3) Muscular or contractile tissue; and

(4) Nervous or sensory tissue.

1. **Epithelial tissue** or **Epithelium** forms the external and internal coverings, such as lining of the gut or the surface of the skin, outer layer of eye-ball, nasal and oral linings etc. The epithelium consists of cells arranged in sheets. The cells are placed compactly and held together by a basement membrane. There is very little intercellular material secreted by the cells. The normal functions of the epithelium are: (i) protection; (ii) absorption; (iii) secretion, etc.

The most common function is secretion; and the secretory part of most glands is made up of epithelium.

The epithelium is of two types: (i) *Simple epithelium,* where the cells are arranged in a single layer, (ii) *Stratified epithelium,* where the cells are arranged in more than one layer (*strata*).

Simple Epithelium

(a) **Squamous epithelium.** It consists of a layer of flattened cells, whose edges fit like the tiles in a floor and hence is called *pavement epithelium.* (Fig. 2) The cells are filled with cytoplasm, and there is a nucleus present in the cells; *e. g.,* Lining of the Alveolus, Wall of the Bowman's capsule.

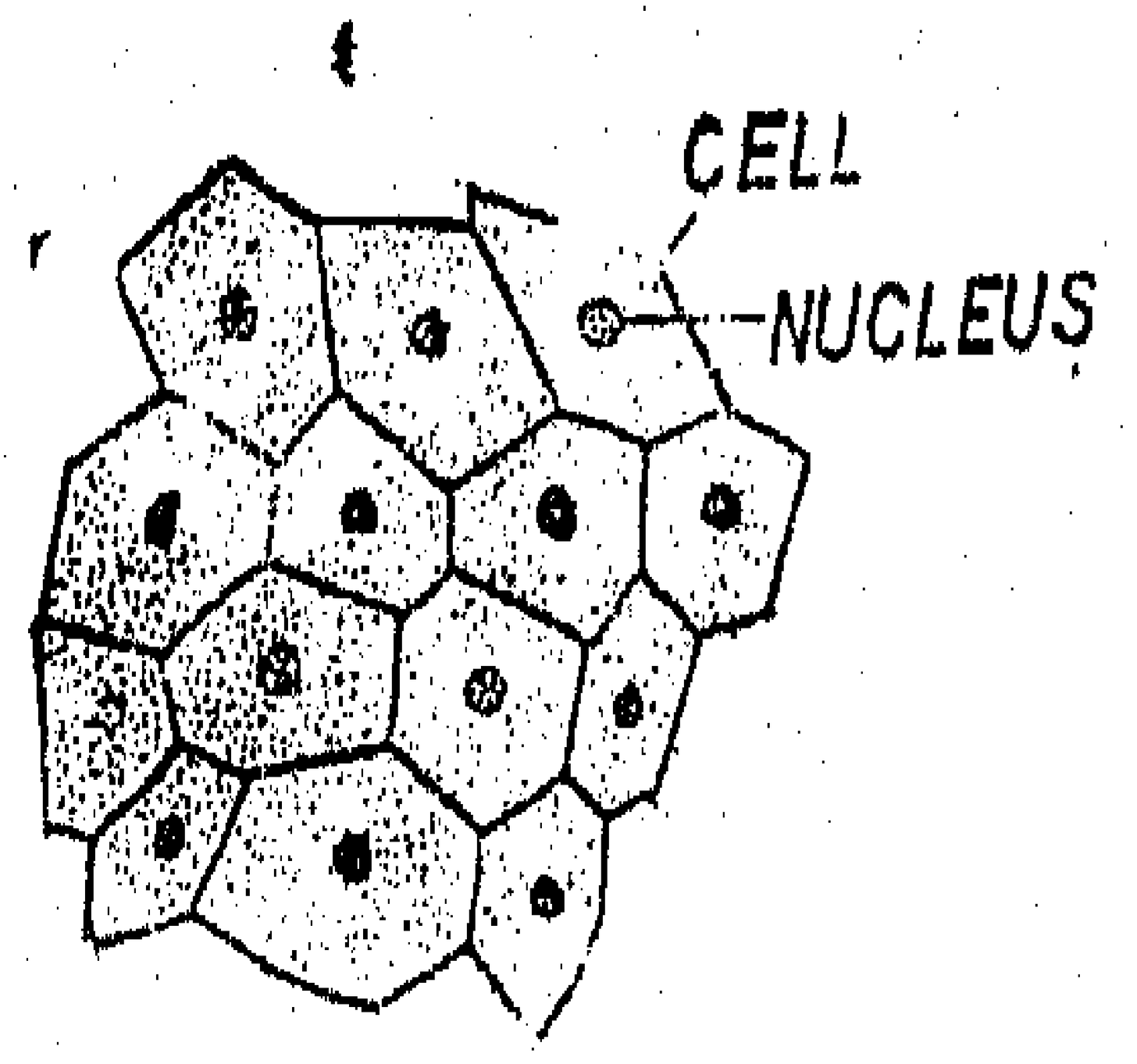


Fig 2. *Squamous epithelium*

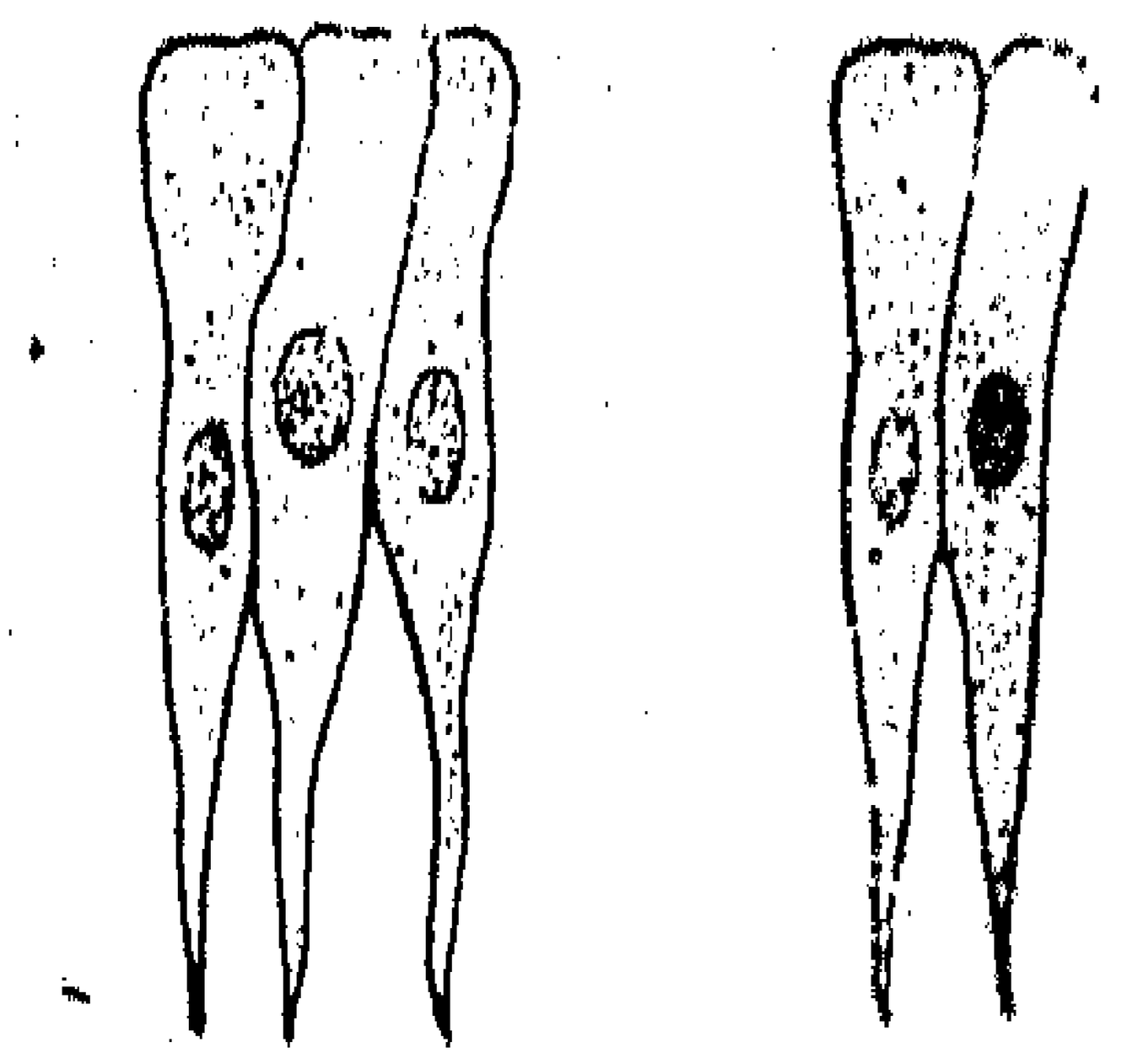


Fig. 3. *Columnar epithelium*

(b) **Columnar epithelium.** In this tissue, the cells are tall, column-like. They are arranged in a single layer. (Fig. 3) The nucleus is elongated along the long axis of the cells; *e. g.,* Internal lining of the stomach and intestine in vertebrates.

2. **Connective tissue.** The connective tissue serves to connect or bind the tissues and organs together. Certain other connective tissues are specialised for functions other than mere binding, such as support (Bone and Cartilage) and transportation (Blood.) They are characterised by the presence of a large amount of intercellular material or a ground substance called *matrix.* This intercellular substance is secreted by the cells of the tissues themselves, and it becomes modified in various ways. In some it remains soft; in others, such as bone, it hardens by the deposits of the carbonates and phosphates of calcium. In blood, it is fluid. Three types of connective tissues are recognised: (i) *Binding or fibrous* (Areolar etc.); (ii) *Supporting* (Skeletal, namely-Bone and Cartilage); and (iii) *Fluid* (Blood).

Areolar tissue. It is the most common and most widely distributed variety of connective tissue, found mostly between the skin and the muscles. (Fig. 4)

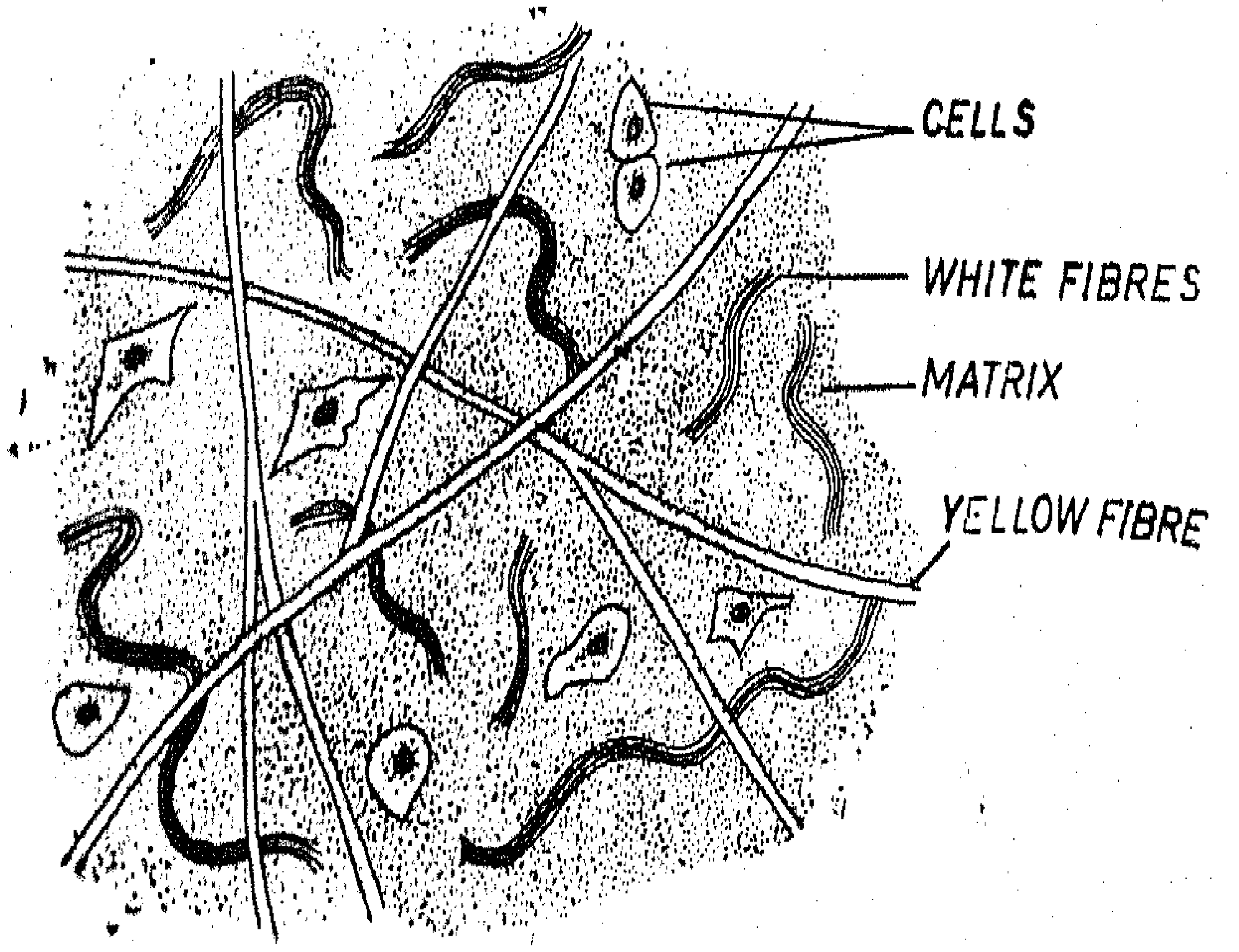


Fig. 4. *Areolar tissue.*

It consists of a clear jelly-like ground substance or *matrix,* in which are embedded connective tissue cells and also interlacing bundles of fine fibres. Fibres are of two kinds:

(a) **White fibres** are unbranched, wavy fibres arranged in bundles and running in all directions. These white fibres are formed of *Collagen* which, when boiled in water, yields a substance called gelatin. This collagen gives the necessary firmness to the tissue.

(b) The yellow elastic fibres are the solitary branched fibres. They are slender and run straight. The fibres are made up of *elastin* which gives elasticity to the tissue.

Some of the connective tissue cells present in the matrix are (i) *Amoeboid histocytes* and (ii) *Fibroblasts* (producing fibres).

Cartilage. Cartilage is a firm but resilient connective tissue. (Fig. 5) It has a clear matrix, which is of a dense and elastic nature. Cartilage cells or *chondrocytes* are embedded in irregularly scattered, fluid-filled spaces called *lacunae*. This matrix contains a few inorganic salts and certain proteins such as *Chondromucoid* and *Chondroalbuminoid*. The cartilage cells (chondrocytes) secrete the matrix. They divide into two or more daughter cells, which often lie in groups of two or more cells.

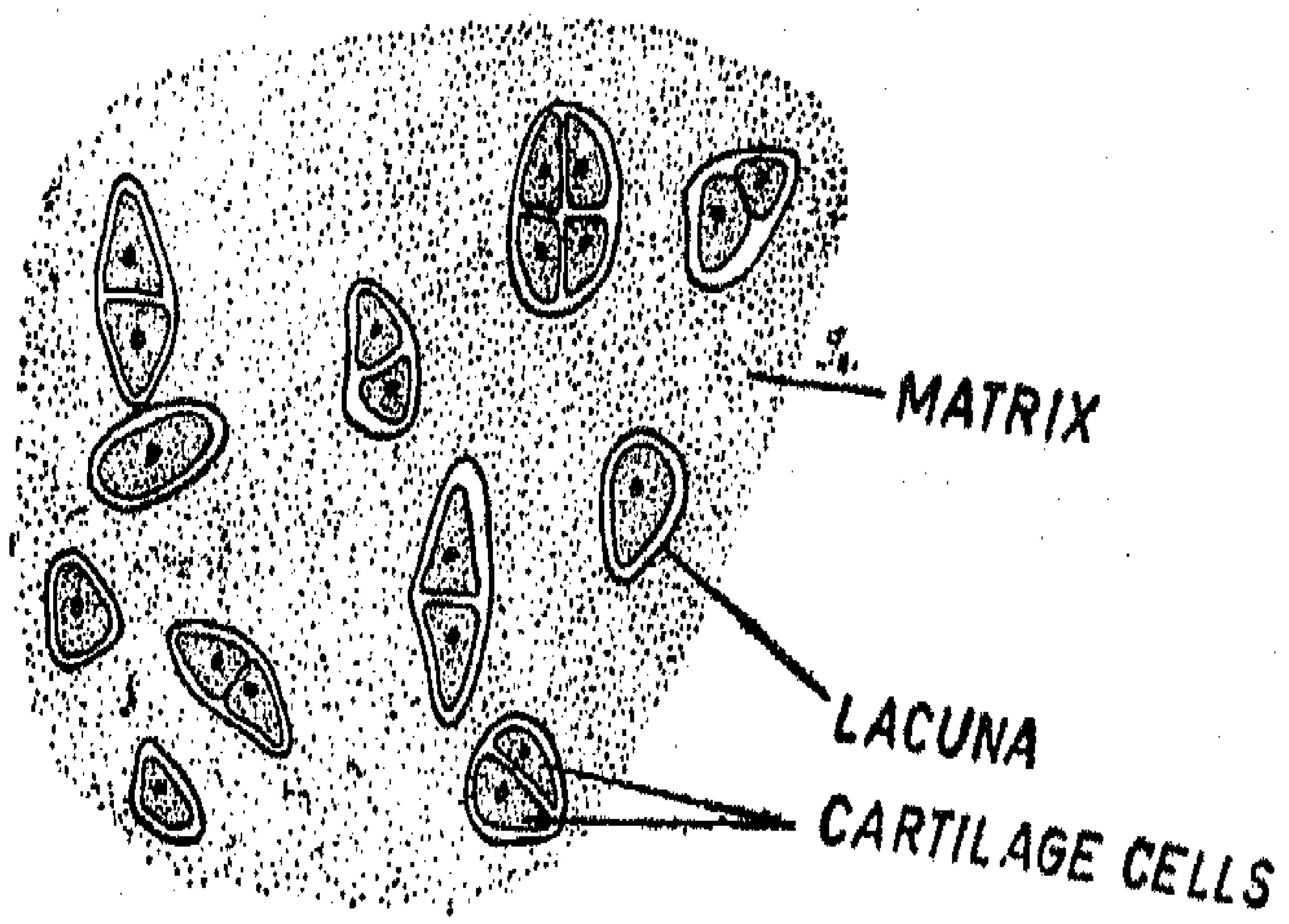


Fig. 5. *T. S. of Cartilage*

The cartilage may be of different varieties (Hyaline, Fibrous or Calcified).

Hyaline cartilage is found in the joints, ribs, cartilages joining the ventral ends of the ribs to the sternum; and also in the cartilage of the nose. It has a large amount of transluscent matrix with less fibres.

Fibrous cartilage is the one in which the matrix is traversed by fibres. It is found in the pinna of the ear, and between vertebrae.

Sometimes, granules of calcium carbonate are deposited in the matrix, and form what is called calcified cartilage, such as the cartilage of the episternum.

Bone (*Human*). Bone is a hard and dense connective tissue. (Fig. 6). It is composed of a hard matrix in which the bone cells or "*osteocytes*" are present. The matrix is heavily impregnated with calcium salts, chiefly phosphates and the proteins, osteo-mucoid and osteo-albuminoid. The bone is covered on the outside by a tough fibrous membrane, the *periosteum*. Just beneath the periosteum lies a layer of cells, the osteoblasts, the bone-forming cells. They multiply, giving rise to new cells, thus adding new bony layers.

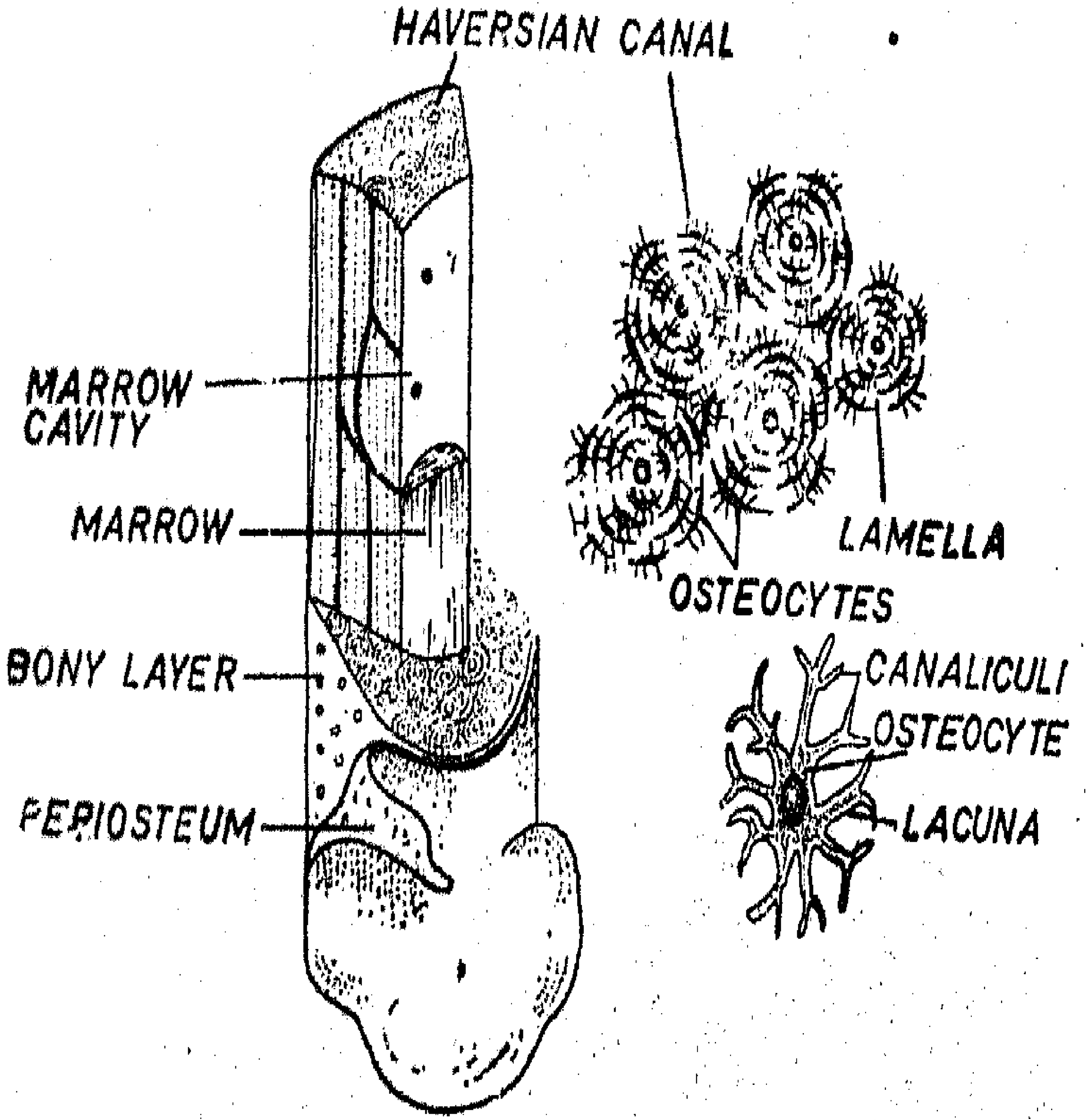


Fig. 6. *Section of Bone* (*Human*)

In the middle of the bone is a longitudinal marrow cavity. It is filled with soft tissue, the *marrow*, which is highly vascular at certain regions, particularly at the ends of the bone and is called the red bone marrow. The cavity of the bone is lined with a more delicate membrane, the *endosteum*. Just beneath the periosteum, and outer to the marrow cavity, the lamellae run parallel to the surface. They are called the inner and the outer circumferential lamellae. The rest of the bony substance is made up of numerous cylindrical units known as the *Haversian systems.* Each system has a central narrow tubular cavity called *Haversian canal,* which contains blood vessels and nerves. These canals are disposed along a longitudinal axis and are interconnected with each other. Each canal is surrounded by concentric rings of a bony substance called *lamellae.* The bony matrix is occupied by numerous scattered osteocytes, each surrounded by a cavity, the *lacuna.* The various lacunae are interconnected by a system of delicate branching canals called *canaliculi.* The branched processes of the osteocytes fill up these canaliculi, thus maintaining an intimate contact with one another. This system of canaliculi ensures the food supply to all the osteocytes of each system.

3. **Muscular tissue.** The muscular tissue is contractile. The muscle is made up of cells, which are long and slender and are called muscle fibres. Two main types of muscle fibres are usually distinguished: the striated or voluntary (also known as skeletal) and the *non-striated* or involuntary or smooth (also known as visceral) muscle fibres.

The voluntary muscles are generally under the control of the will. These are normally concerned with the movement of the body. Involuntary muscles occur in the muscular coat of the alimentary canal, in the wall of blood vessels, in the lungs, urinary bladder, etc. These muscles are quite independent of the will in their action.

Muscles of the heart (cardiac muscles), though of the striated nature, are involuntary in function.

Striated muscle. A striated muscle fibre is long and cylindrical. (Fig. 7) Each cell is surrounded by an outer covering membrane called *Sarcolemma.* Several elongated nuclei are scattered in each cell. The cell thus is syncytial in nature (the syncytium is a sheet of cytoplasm with the numerous nuclei scattered around). The cytoplasm of this muscle fibre, which is referred to as *sarcoplasm,* shows several longitudinal fibrils, the *myofibrils.* Each fibril shows a series of alternate dark and light transverse bands or discs which give the entire fibre its striated appearance. Between the fibrils, there is a semi-fluid substance known as the *sarcoplasm.*

Muscle fibres are arranged in bundles, and these bundles are bound together by connective tissues to form a muscle.

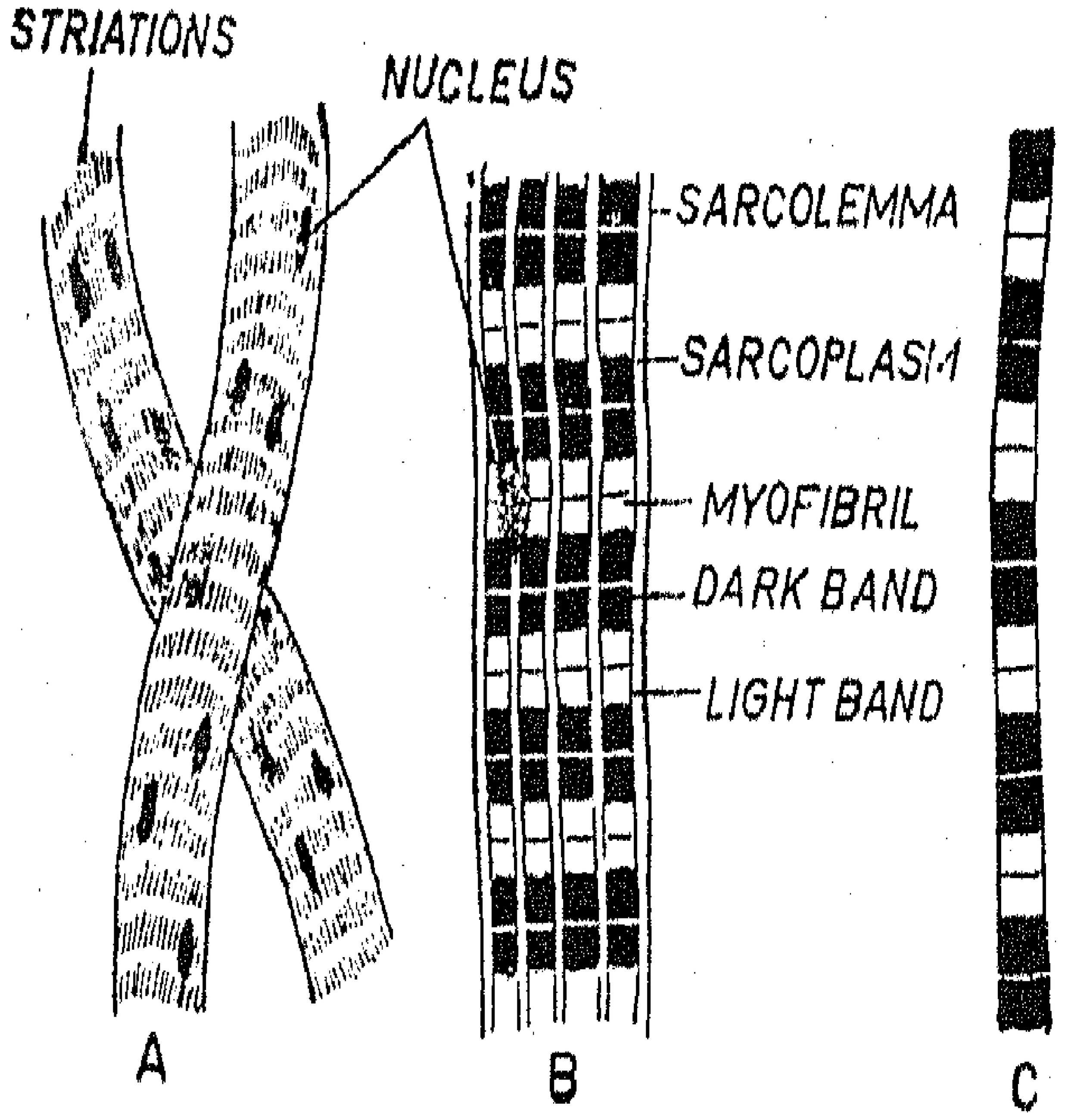


Fig. 7 (**A**) *Striated muscle fibre* (**B**) *Striated muscle fibre (magnified),* (**C**) *Simple myofibril*

Non-striated muscle. A non-striated muscle (Fig. 8) is composed of small spindle-shaped cells, with a single nucleus near the centre. The nucleus is elongated in the direction of the fibre.

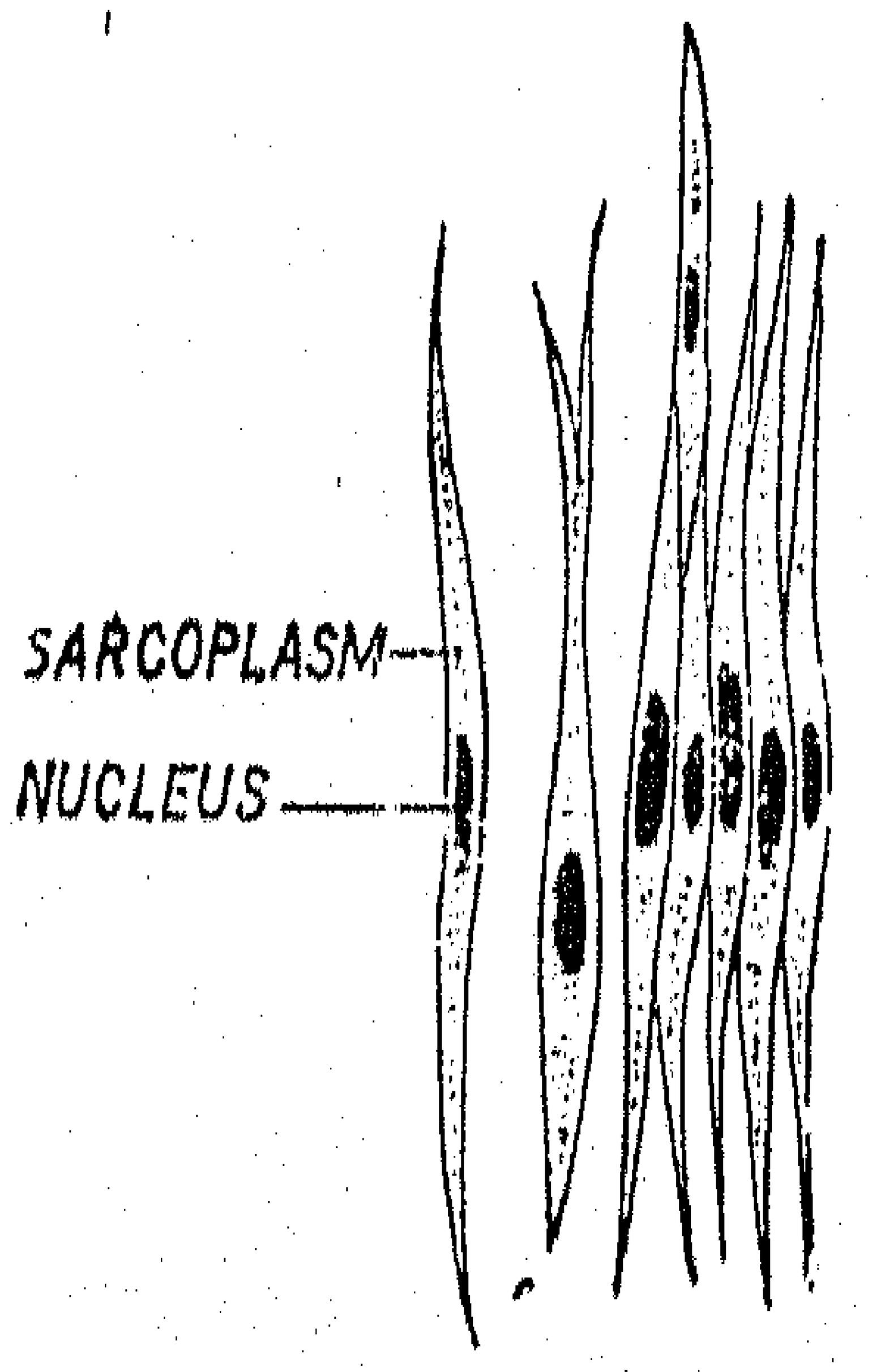


Fig. 8. *Non-striated muscle*

The cytoplasm contains longitudinally-placed myofibrils, which lack the transverse bands. The cells or fibres are not surrounded by a special membrane, and are joined with one another by a very delicate system of loose connective tissues. The ends of the fibres are sometimes branched.

4. **Nervous tissue.** It consists of nerve cells called *neurons.* Millions of neurons aggregate together with other less differentiated supporting cells, the *neuroglia,* to form the nervous matter constituting the brain and the spinal cord. A neuron is a specialised cell modified for the conduction of impulses. A typical neuron consists of a central nucleated portion, the cell body (*cyton*) and the processes originating from it. The cyton is a star-shaped structure with a granular cytoplasm. The granules of the cytoplasm are called *Nissle granules.* These are considered to be store-houses of nervous energy. The cytoplasm also shows a network of neuro fibrils, which appear to pass into the processes arising from the cyton. Neurofibrils are supposed to conduct the impulses.

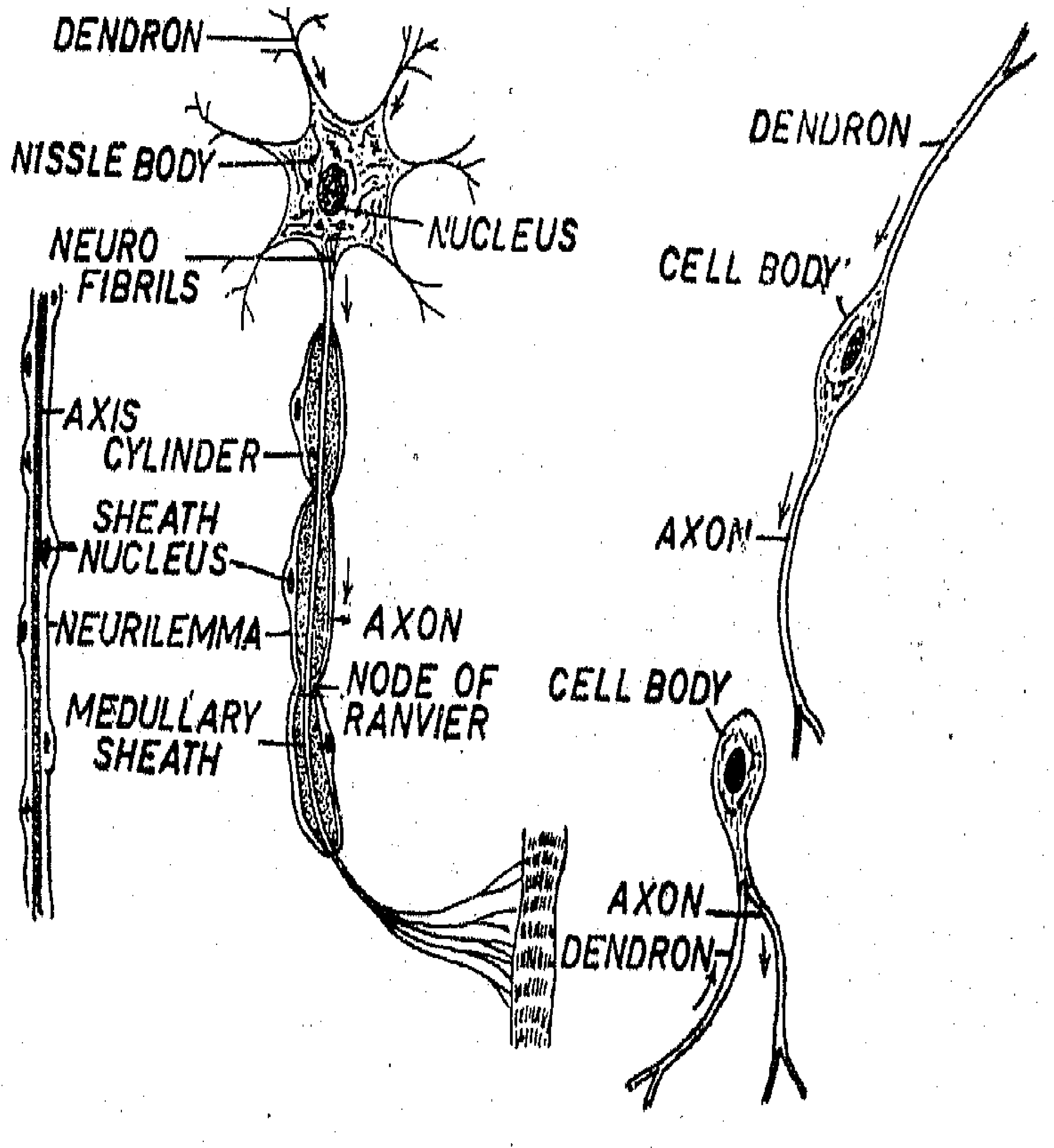


Fig. 9. *Neurons*

From the cell body, a number of branching processes is given out, of which one is usually long, while the others are smaller. The process through which the cyton receives the impulses is called as dendron and the one through which they are carried away from the cell body is called as axon. Thus these two types of fibres are functionally different. The number of processes arising from a neuron is variable. Accordingly, they are classified as either *unipolar, bipolar* or *multipolar.* (Fig. 8A) In a multipolar neuron, numerous processes arise from all sides. In a bipolar neuron, two branches arise from the two opposite poles. In a unipolar neuron, the processes are two, but they arise close together from one pole and not from the opposite poles.

On the basis of their functions, neurons may be either *afferent* (sensory) or efferent (motor). The afferent or sensory neurons are those which carry impulses from sense organs (receptor organs), such as the skin, to the central nervous system, while the efferent or motor neurons are those which carry motor impulses from the central nervous system to the effector organs such as the muscles or glands.

The *axon* is a typical nerve fibre. It is formed from the numerous neurofibrils which arise from the cell body. When a group of such axons or dendrites unite, a nerve is formed. Each nerve fibre consists of an axis called *axis-cylinder,* which is the direct continuation of the cyton. Surrounding the axis is the covering layer of some fatty material called *myelin.* This sheath of fat is called the *medullary sheath.* Externally, it is covered by a delicate membrane, the *neurilemma.* The myelin sheath is not continuous throughout the length of the fibre; it is absent at intervals. At these points, the neurilemma dips in to form constrictions called *nodes of Ranvier.* The space between two successive nodes is called the internode. Scattered here and there beneath the neurilemma are found the nuclei called the *sheath nuclei.* Usually, each internode contains a nucleus.

Nerve fibres are of two types, depending on presence or absence of the sheath of myelin. Nerve fibres, where the medullary sheath is present, are known as *medulated;* and where it is absent, they are known as *non-medulated* nerve fibres. (Fig. 9)

SUMMARY

1. A specialised group of cells get bound together to form tissues.
2. The four major types of animal tissues are :—

   (a) Epithelial (b) Connective (c) Muscular and

   (d) Nervous.
3. Epithelial tissues form external and internal coverings such as lining of the gut or the surface of the skin.
4. Functions of epithelial tissues are (1) Protection (2) Absorption and (3) Secretion.
5. Connective tissues bind tissues and organs together.
6. Muscular tissues are contractile. There are two types, namely, (i) Striated or voluntary and (ii) non-striated or involuntary.
7. Nervous tissue consists of nerves, which conduct impulses.

BIOLOGICAL WORDS

Tissue
Organ
System
Epithelial tissue
Squamous
Columnar
Cartilage

Haversian canal
Axon
Neuron
Myelin
Neurilemma
Sarcolemma
Collagen.

QUESTIONS

1. What is a tissue? Describe any three of the animal tissues studied by you.
2. Write short notes on:—

   (a) Haversian system, (b) Epithelium, (c) Neuron, (d) Striated muscle fibre, (e) Areolar tissue.
3. Distinguish between:—

   (i) Striated muscle and unstriated muscle.
   (ii) Neuron and Nephron.
   (iii) Cyton and Axon.
   (iv) White fibres and yellow fibres.

Animal Classification

5

In nature, we come across such innumerable varieties of animals which differ in form, size and structure that any layman gets confused; and it becomes difficult for him to get acquainted with all of them. Therefore, to get a proper perspective of the entire animal kingdom, some means is necessary to group them for purposes of study. This is one of the reasons for the science of classification. The first purpose of classification is convenience; but the most important one is to show relationship.

Among the several kinds of animals there appear to be some kind of resemblances and some differences as well. The presence of such resemblances and differences has formed a basis for classifying the animals into definite groups, either minor or major.

This scientific method of orderly arrangement, grouping or classifying the different animals on the basis of their similarities and dissimilarities so as to show their presumed relationships with one another is known as *classification* or taxonomy or *systematic zoology.*

Classification may be based on superficial resemblances in structure, colour and habitat, and therefore may be artificial; or it may be natural. Natural classification is based chiefly on their characters or inherent peculiarities, and features, either external or internal, *i.e.*, *morphological* or *anatomical*; gross or *microscopical*, *i.e.*, *histological*; or it may be embryological.

It was *Carolus Linnaeus* (1707-1778), a Swedish naturalist in the 18th century, who successfully founded a scheme of natural classification, which is followed even today.

He divided the *animal kingdom* into a number of clearly defined major groups called as *Phyla* (singular—*phylum*). These major groups are further divided into sub-groups known as *classes*; classes into *orders* and orders into *families*; families into *genera* (singular—*genus*), and genera into *species.*

Species is considered to be the basic unit in biological classification. It is an assemblage or group of individuals having many characters in common. The individuals of a species are derived from a common ancestry, related by blood, and can breed with one another to produce offspring which resemble the parents.

Common examples of the species are the cat, tiger, pigeon, frog, house-fly, etc.

Two or more species, that resemble each other closely—such as lions, tigers, leopards and cats having certain characters in common —are grouped together as a genus. Each species under the genus is then named by a double name, the first one referring to the genus (called the generic name) and the second one referring to the species (called the specific name). Thus the scientific name of the lion is *Felis leo*, that of the tiger is *Felis tigris*, that of the common Indian frog is *Rana tigrina* and that of man is *Homo sapiens*.

In this combination of two names, the generic name starts with a capital letter and the specific name is written in small letters.

This method of designating an animal by two names is known as the *binomial system of nomenclature*. It was devised by Carolus Linnaeus, who thus divided and sub-divided the entire animal kingdom till he came down to species and gave each species a distinct name.

This method of naming a species not only provides a distinct name for each kind of animal but also serves to indicate relationships, for closely related species receive the same generic name.

Genera, bearing a certain degree of resemblance, are united into a family. Families, with common characteristics, together constitute an order. Orders displaying important similarities are placed in a class. In a similar manner, animals of different classes, having common anatomical construction, from a phylum. Thus a phylum represents one of the major divisions of the animal kingdom.

For convenience, the entire *animal kingdom* is divided into two groups, *Chordates* and *Non-chordates*.

The group *Chordata* is considered to be a phylum and is divided into four sub-phyla, one of which is the *Vertebrata*, which includes animals possessing a backbone or vertebral column; *e.g.*, fishes, frogs, reptiles, birds and mammals.

Non-chordata includes all forms which do not possess a vertebral column, and therefore are treated as *Invertebrate*. This major group includes nine phyla.

While the vertebrates comprise the greater part of the phylum chordata, there are several other animals which do not possess a vertebral column and yet are included in this phylum because they possess certain characteristics in common with the vertebrates. These groups of animals are considered to be lower chordates or invertebrate chordates.

I. Main *Chordate* characteristics are :

1. Presence of a *Notochord*. (Notochord is a rod of cells lying dorsal to the alimentary canal, extending from the anterior to the posterior end and serving as a skeletal support. In vertebrata, this is partially or completely replaced by the vertebral column.)

2. Possession of pharyngeal clefts or gill slits, either in the embryo or throughout life.

3. A central nervous system, which is a hollow tubular nerve cord.

II. The most outstanding characteristics of the animals included under the sub-phylum *Vertebrata* are :

1. Possession of a vertebral column or backbone formed of a chain of bony units known as the vertebrae.

2. The presence of a skull or cranium that encloses the brain.

3. The nerve cord is dorsal and tubular and consists of the brain and the spinal cord, from which nerves are given off in pairs to the body.

4. Head with three pairs of sense organs.

5. Presence of two pairs of appendages like fins or limbs for locomotion.

6. The pharynx bears a small number of gill openings or clefts. These may be present throughout life, as in fishes, or may

be present only during the embryonic life, as in animals which breathe by lungs in the adult stage.

7. The heart is ventral to the alimentary canal.

8. Circulating fluid, the blood, containing a respiratory pigment called the *haemoglobin* and red blood corpuscles.

9. Presence of a hepatic portal asystem.

10. Respiration takes place with the help of gills in most of the aquatic forms and with lungs in the terrestrial and aerial forms.

11. The excretory organs are the kidneys composed of numerous tubules, known as the uriniferous tubules.

12. The sexes are always separate.

III. The characteristics of the *Invertebrate* group of animals are :

1. Absence of the backbone.

2. The heart, when present, is dorsal.

3. The nerve cord, when present, is ventral to the alimentary canal and is solid.

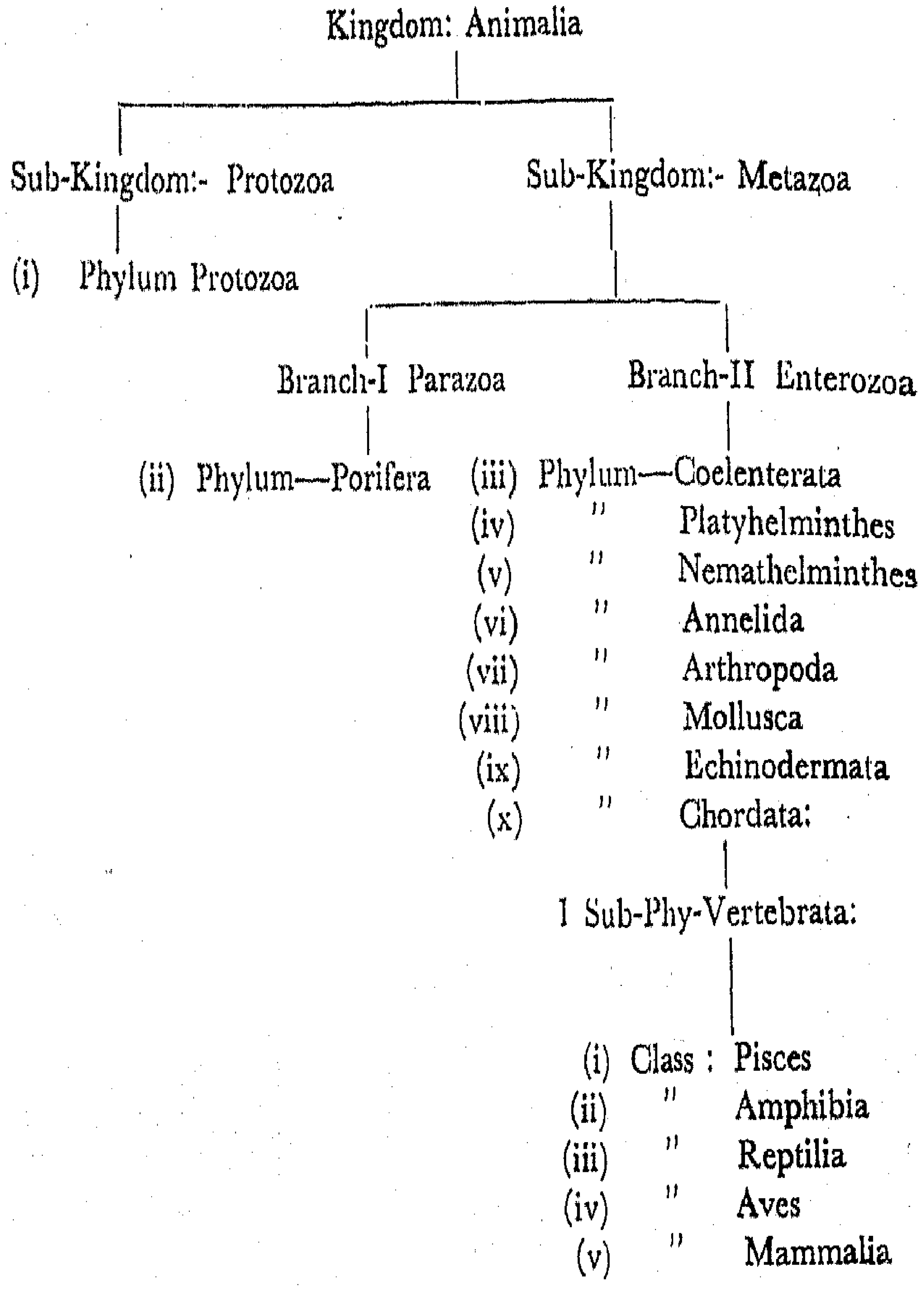
4. There are no gill clefts.

Even though the entire *animal kingdom* is divisible into Chordata and Non-chordata, the more up-to-date and convenient method of classifying it would be to divide it into two sub-kingdoms, namely, Sub-kingdom: *Protozoa*, and Sub-kingdom: *Metazoa*.

The *Protozoa* are individuals having a body which is not divided into cells *i.e.*, they are *acellular*.

Metazoa are animals which are *cellular*, for they have the body sub-divided into number of cells, i.e., they are multicellular.

Sub-kingdom Metazoa is further sub-divided into two branches: *Branch* I, *Parazoa*; *Branch* II, *Enterozoa*.



Sponges are grouped under the Parazoa, since the cells do not form definite tissues and organs but are loosely aggregated. They have no digestive cavity or mouth, as in the case of the Enterozoa.

The Enterozoa (or Eumetazoa) includes individuals in which the cells are organised into tissues and organs, and the body wall is made of either two or three germinal layers. There is a well-defined digestive cavity with a mouth, and, in most cases, an anus.

Sub-kingdom : *Protozoa* includes a single phylum (i) Phylum—*Protozoa*.

Branch I: *Parazoa* includes the only phylum: (ii) Phylum—*Porifera*.

Branch II: *Enterozoa* includes the rest of the phyla, namely, (iii) *Coelenterata*, (iv) *Platyhelminthes*, (v) *Nemathelminthes* (*Nematoda*), (vi) *Annelida*, (vii) *Arthropoda*, (viii) *Mollusca*, (ix) *Echinodermata*, and (x) *Chordata*.

Phylum: *Chordata* is further subdivided into four sub-phyla, and the *Vertebrata* constitutes one of the sub-phyla.

Sub-phylum: *Vertebrata* is divided into five main classes:

(i) Class:- *Pisces* (Fishes),
(ii) Class:- *Amphibia* (Amphibians),
(iii) Class:- *Reptilia* (Reptilians),
(iv) Class:- *Aves* (Birds), and
(v) Class:-*Mammalia* (Mammals)

Sub-kingdom—Metazoa thus includes invertebrate and vertebrate groups of animals.

Phylum-Protozoa

These are acellular animals where the body is normally with one or more nuclei. They are mostly composed of a single cell, and are solitary or colonial. They usually require moisture, but can live in varied conditions or habitats. They are found in fresh water or in salt water. A few others live in debris or decaying organic matter. They are either freeliving or parasitic or saprophytic. Some of the parasitic forms cause diseases such as malaria, dysentery and sleeping sickness in man.

Protozoans, though single celled, can carry on all the essential vital functions of life, as in other multicellular organisms. The single cell of the animal gets differentiated into definite regions, specialised to perform the varied functions of the body. These specialised regions are called *organelles* (*e.g.*, Contractile Vacuole and food vacuoles).

The locomotion is achieved either by temporary *pseudopodia*, as in Amoeba, or by the help of the lashing movements of the whip-like *flagella*, as in Euglena, or by the beating movements of the short hair-like processes the *cilia*, as in Paramecium. Digestion takes place within the cell, and hence is intra-cellular. Reproduction is normally asexual by a process of division or fission, called binary or multiple fission. In some, there is a process called conjugation, in which the exchange of nuclear material between the two uniting individuals takes place; *e.g.*, Amoeba, Euglena, Paramoecium, Nocticula, and Plasmodium vivax.

Amoeba. It is found in the mud of ponds. (Fig. 10) It is a mass of protoplasm bounded by a thin membrane, the *plasmalemma*. It has no definite shape, since it constantly changes its shape due to the streaming movements of its protoplasm. The protoplasm is differentiated into an outer, clearer and firmer layer, the *ectoplasm*, and an inner, more fluid granular mass, the *endoplasm*. In the centre of the endoplasm lies the single nucleus. A clear *contractile vacuole* is seen in the endoplasm. This is excretory and osmoregulatory in function. Scattered all over the cytoplasm may be seen one or more food vacuoles containing bits of food.

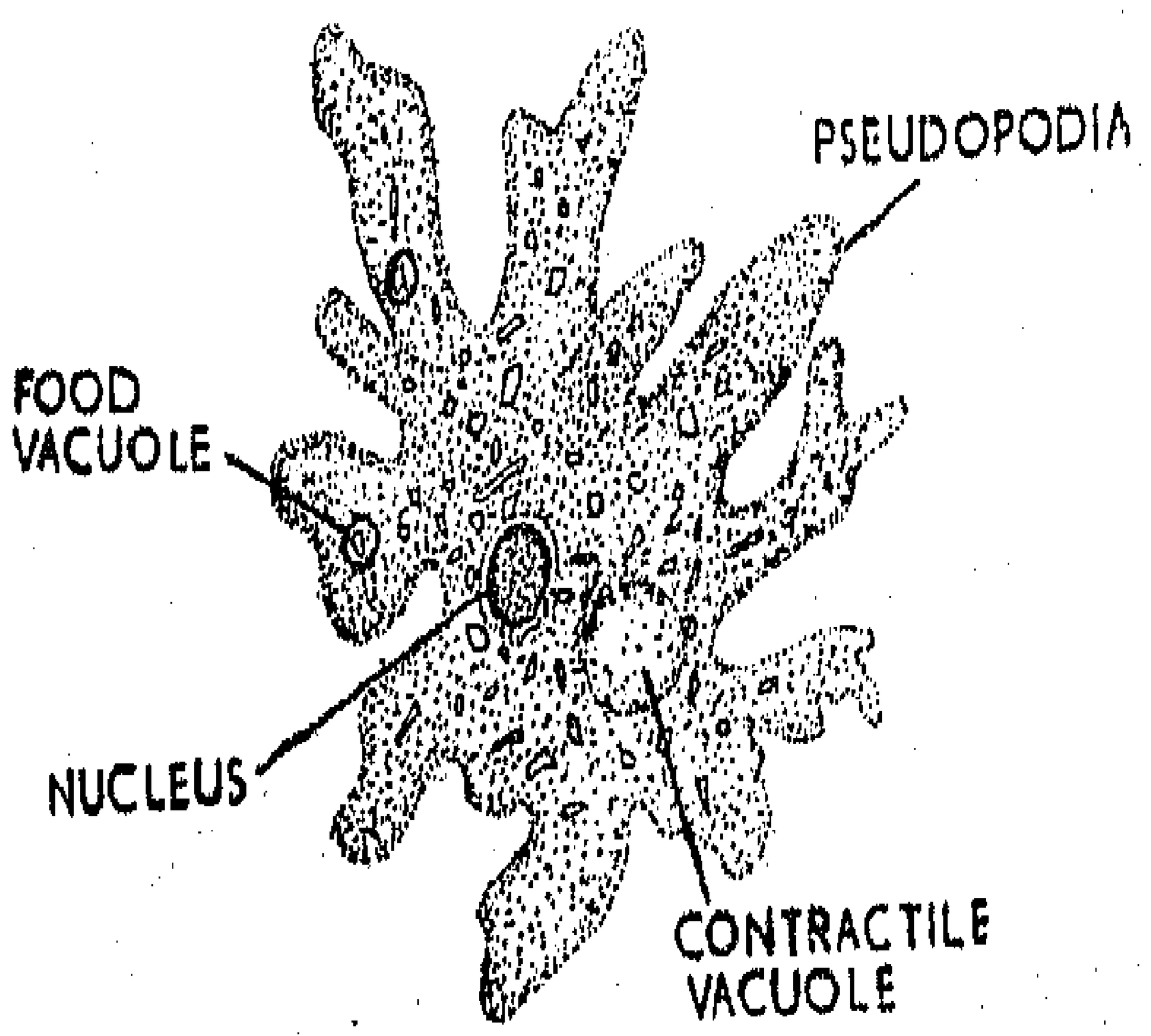


Fig. 10. *Amoeba*

Locomotion is achieved by blunt protoplasmic processes, the *pseudopodia*, which are thrust out in different directions. The amoeba reproduces by a simple division of the body, either by binary fission, where the body divides into two daughter individuals, or by multiple fission, wherein the amoeba undergoes encystation and then divides into a large number of units, each of which gives rise to an amoeba.

Paramoecium. It is also known as *slipper animalcule* (Fig. 11) because of its slipper-like shape. It is common in fresh water which contains decaying vegetation. Due to the presence of a definite outer membrane, the *pellicle*, it has an unchanging and definite shape. It is elongated, blunt anteriorly and tapering at the

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posterior end. The pellicle is covered with fine cilia, which are the protoplasmic outgrowths. The beating of these cilia brings about the movement in these animals. There are two nuclei, a small, rounded micronucleus which is partly surrounded by a larger macronucleus. It has an oral groove opening back into a short gullet, which ends in the cytoplasm. This is the passage for the food material to enter the body. Towards either end of the body there is a contractile vacuole, each one surrounded by a few radiating canals.

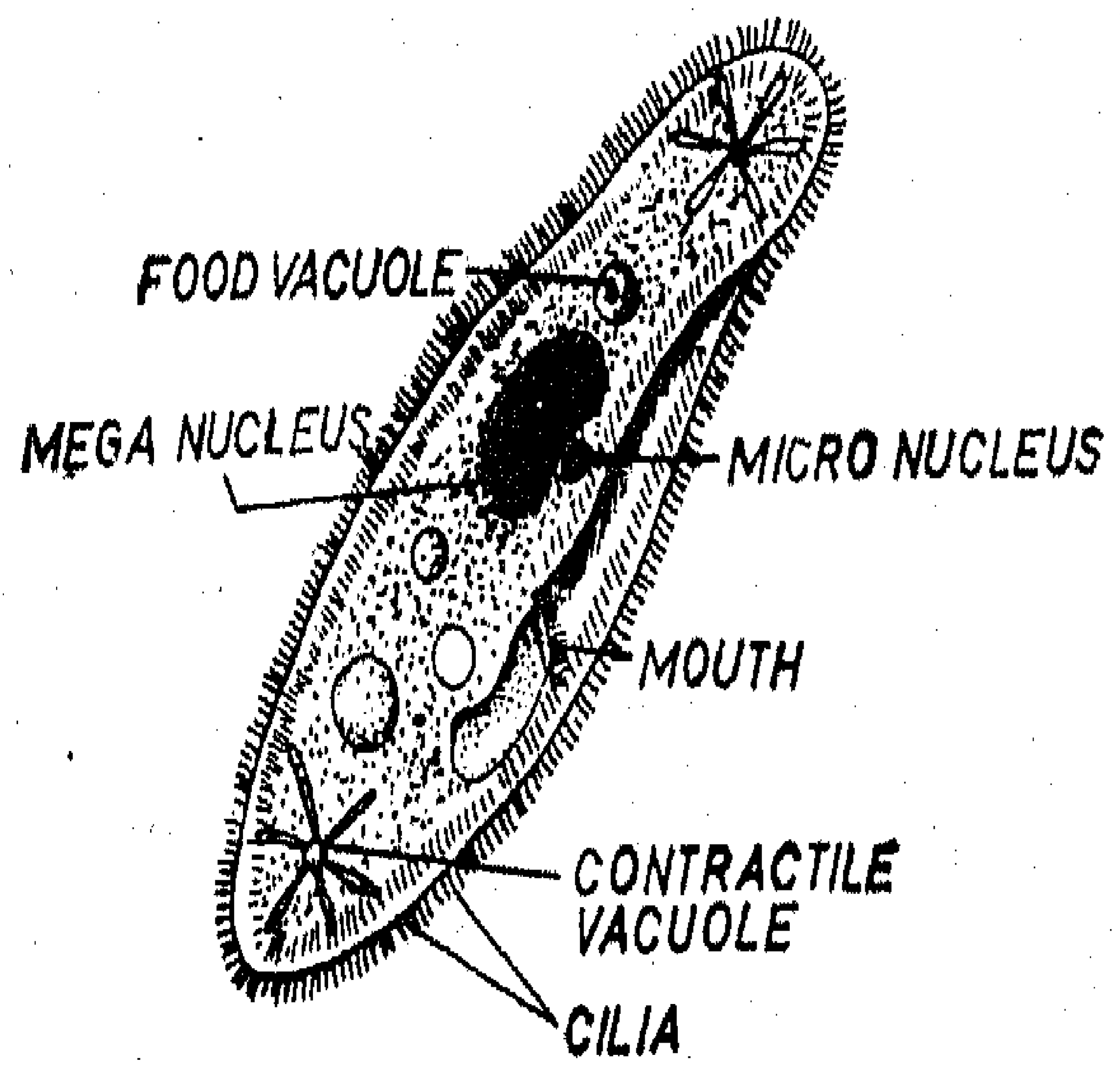

Fig. 11. *Paramoecium*

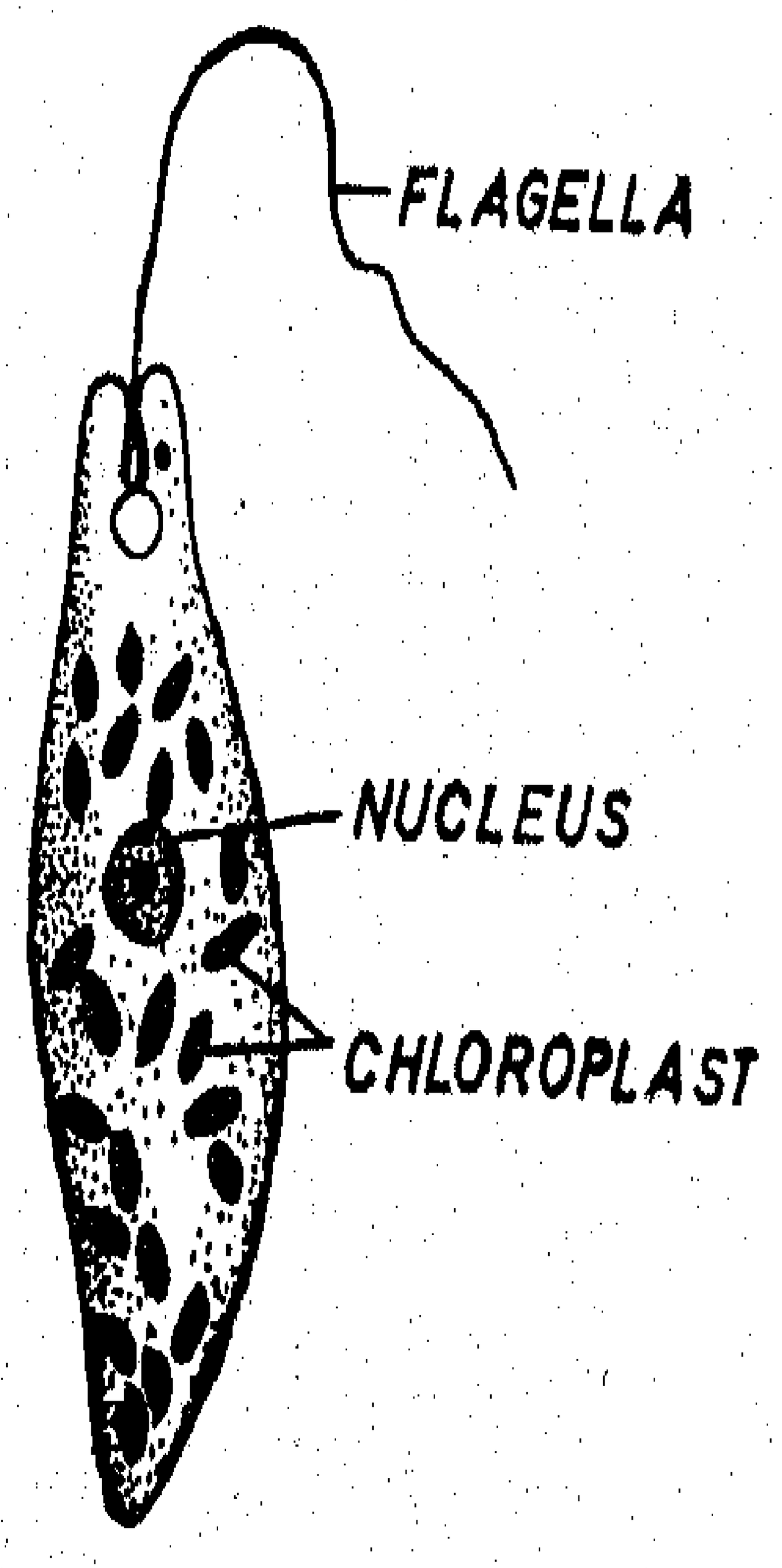

Fig. 12. *Euglena*

Euglena. These are free living animalcules (Fig. 12), which contain chlorophyll, as in plant cells. From the blunt anterior end extends a long whip-like flagellum. Due to the lashing movements of the flagellum, the animals make progression in water, where they live.

Noctiluca. They are protozoans found in the sea. They are luminescent, i.e., they glow in the dark without producing heat in the process.

Plasmodium vivax. It is a parasitic protozoan which causes malarial fever in human beings. It is transmitted from man to man by the bite of mosquitoes belonging to the genus-Anopheles.

Phylum-Porifera

All the sponges are included in this phylum. They are aquatic animals, mostly marine. Some are found in fresh water. They are multicellular and are incapable of any movement. They are varied in shape. Even though the cells are arranged to form a body wall of two layers, they are not organised into tissues and organs, but form only a loose aggregation of cells, supported by an internal skeleton of spicules of calcium carbonate, or silica or of spongin fibres. The outer layer is the dermal layer made of flat cells, while the inner gastral layer is made up of flagellated collared cells (choanocytes). There are innumerable pores on the surface of the body. These pores lead into water canals which in turn, open into a cavity called the gastral cavity. Gastral cavity is lined with choanocytes and it opens to the outside through a larger opening, the *osculum* (not the mouth). Water flows through the pores (ostia) into the water canals present in the body wall, and then into the gastral cavity, from where it flows to the outside through the osculum. There is neither a mouth nor a digestive tract. Digestion is intracellular, for it takes place within the flagellated cells. There are no nerve cells.

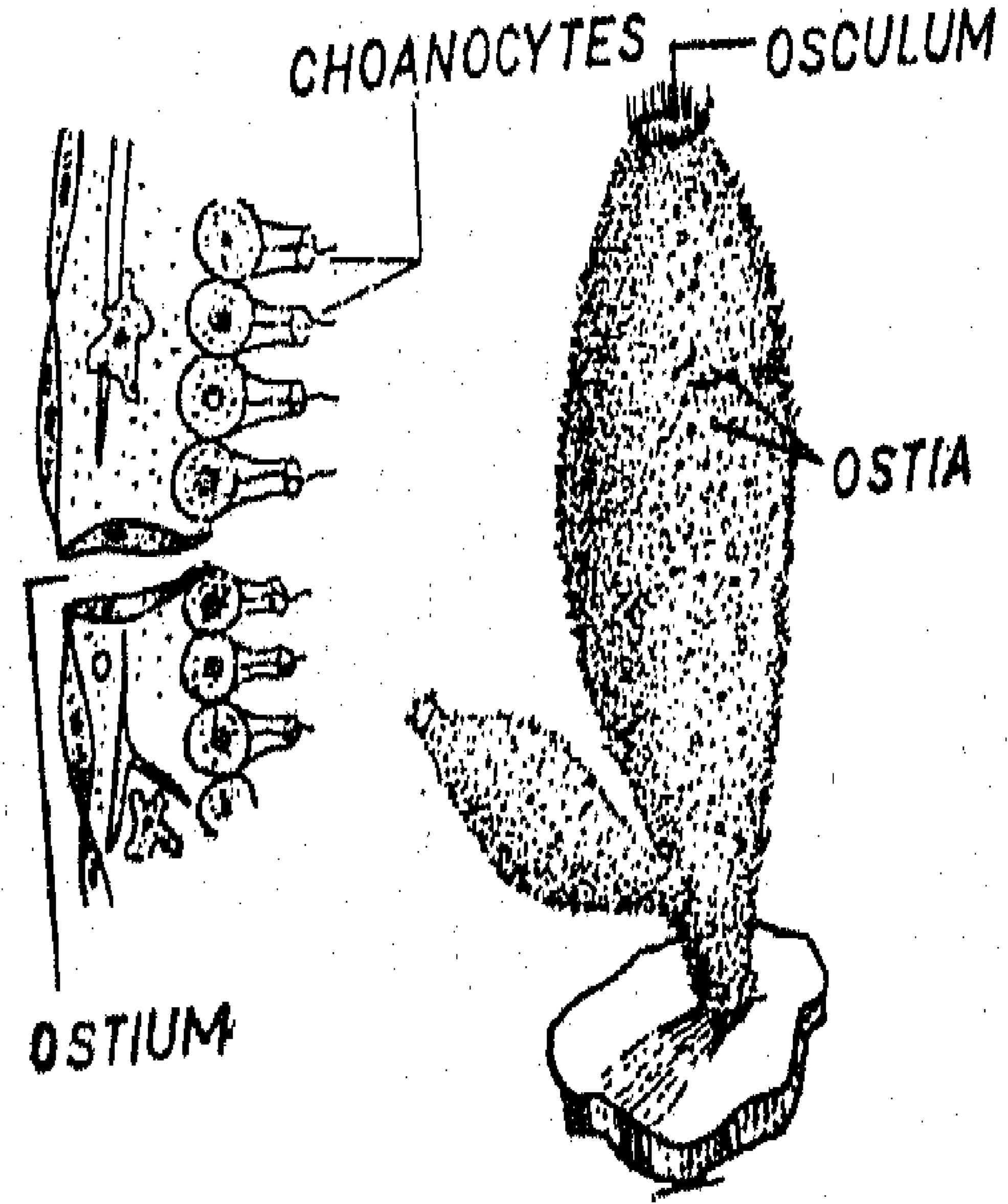

Fig. 13. *Simple sponge (grantia) body wall magnified*

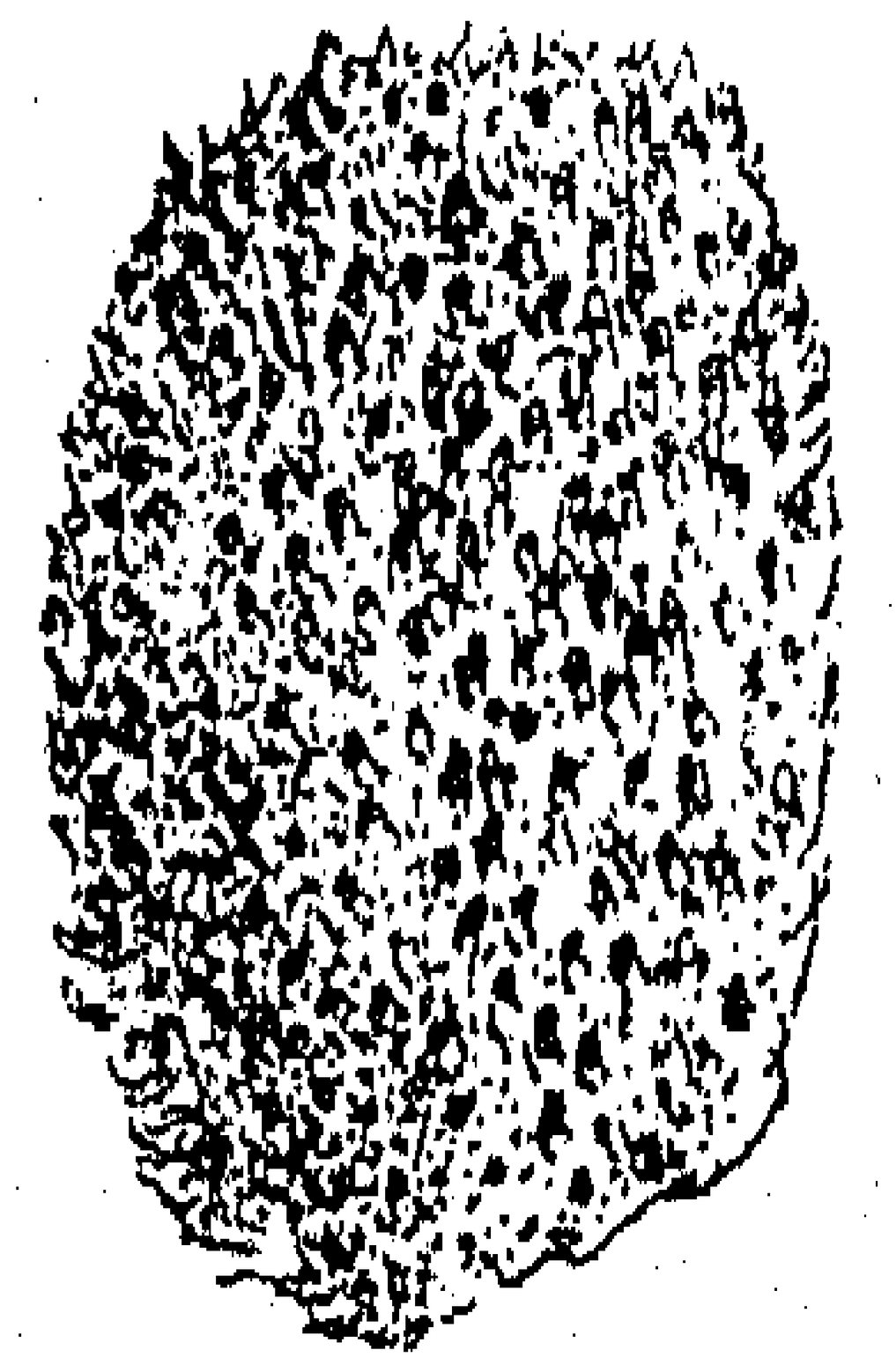

Fig. 14. *Bath Sponge*

Reproduction is asexual by budding or by formation of gemmules, and also by the sexual method with the production of eggs and sperms; *e.g.*, Sycon, Grantia (Fig. 13), Spongilla (Fresh-water sponge), and Bath sponge.

Bath sponge. It is marine. (Fig. 14) The skeleton is of spongin fibre. It is of commercial importance and is used for washing and mopping. It is allowed to decay, then washed; and, by a process of beating, all but its flexible skeleton is removed. This cleaned sponge is marketed as commercial sponge.

Phylum-Coelenterata

They are multicellular, diploblastic, and radially symmetrical animals. They are aquatic, mostly marine, sessile or free-swimming forms, either solitary or in colonies. They exist in two forms namely, (1) the fixed polyp form (with a tubular body having an anterior mouth surrounded by tentacles), and (2) the free-swimming medusa with an umbrella shaped body margined with tentacles. The body wall is of two layers, the outer ectoderm and the inner endoderm, with a non-cellular jelly-like substance, the *mesoglea*, in the middle. They are, therefore, called diploblastic. The nematocysts (the so-called stinging cells), which are used as organs of defence and offence, are present in the body wall. The mouth is surrounded by a circle of tentacles. This leads into a digestive cavity, the gastro-vascular cavity or *coelenteron*, which is lined with endodermal cells. There is no anus. The nervous system is in the form of a "nerve net" formed of scattered nerve cells (protoneurons), and joined together by nerve processes beneath the outer layer of the ectoderm. Reproduction is by asexual method such as budding and fission and also by sexual method. Alternation of generations

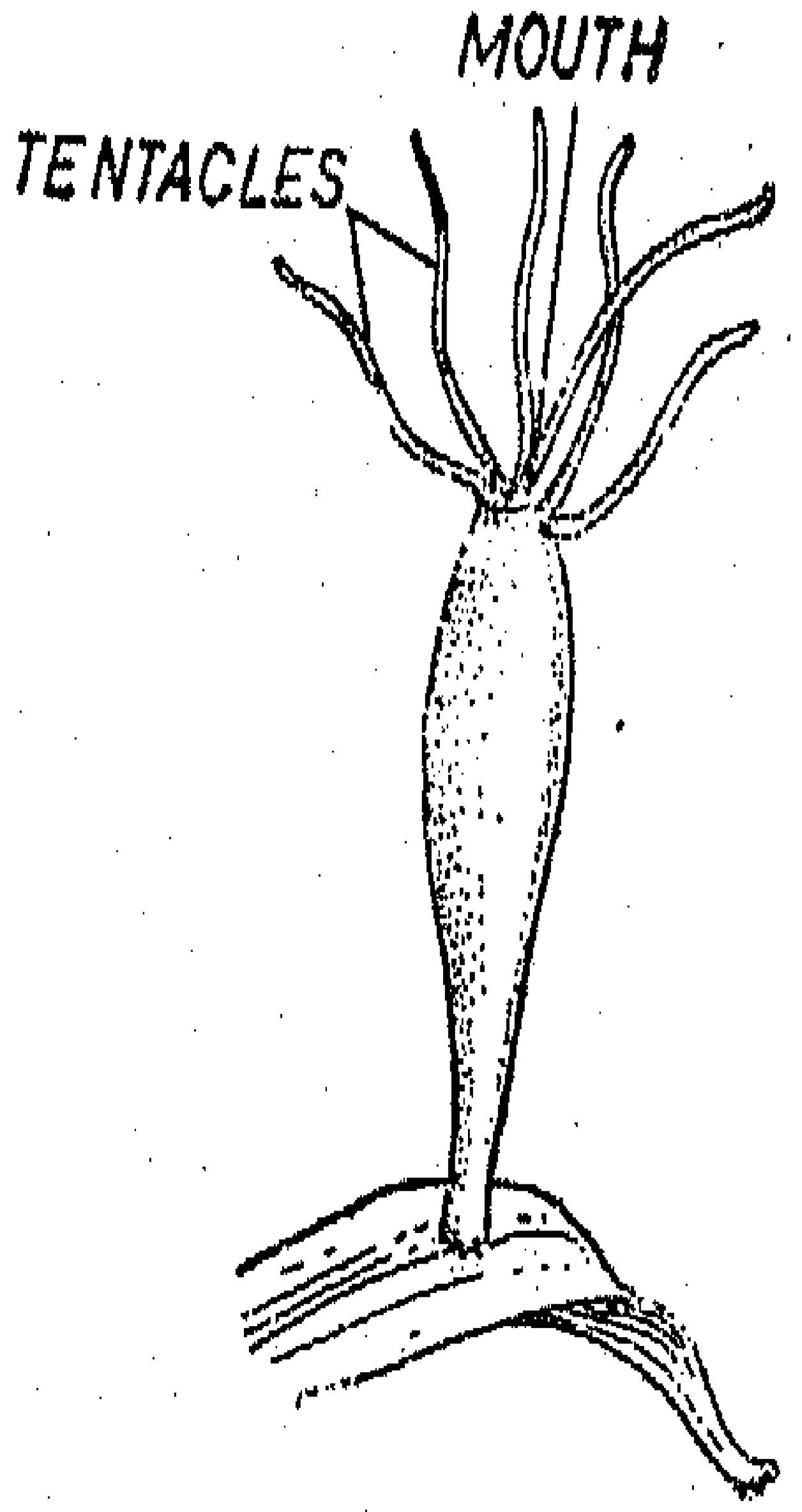

Fig. 15. *Hydra*

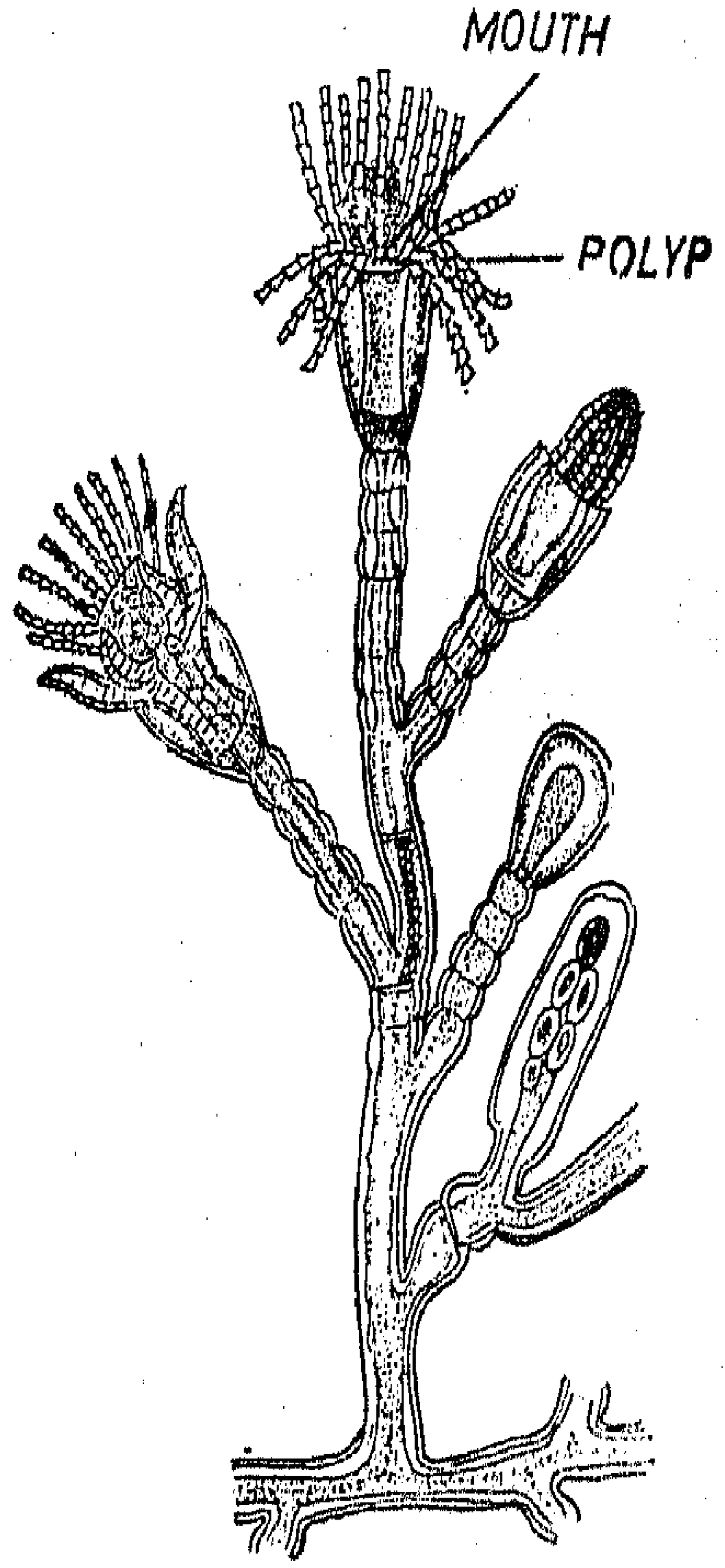

Fig. 16. *Obelia*

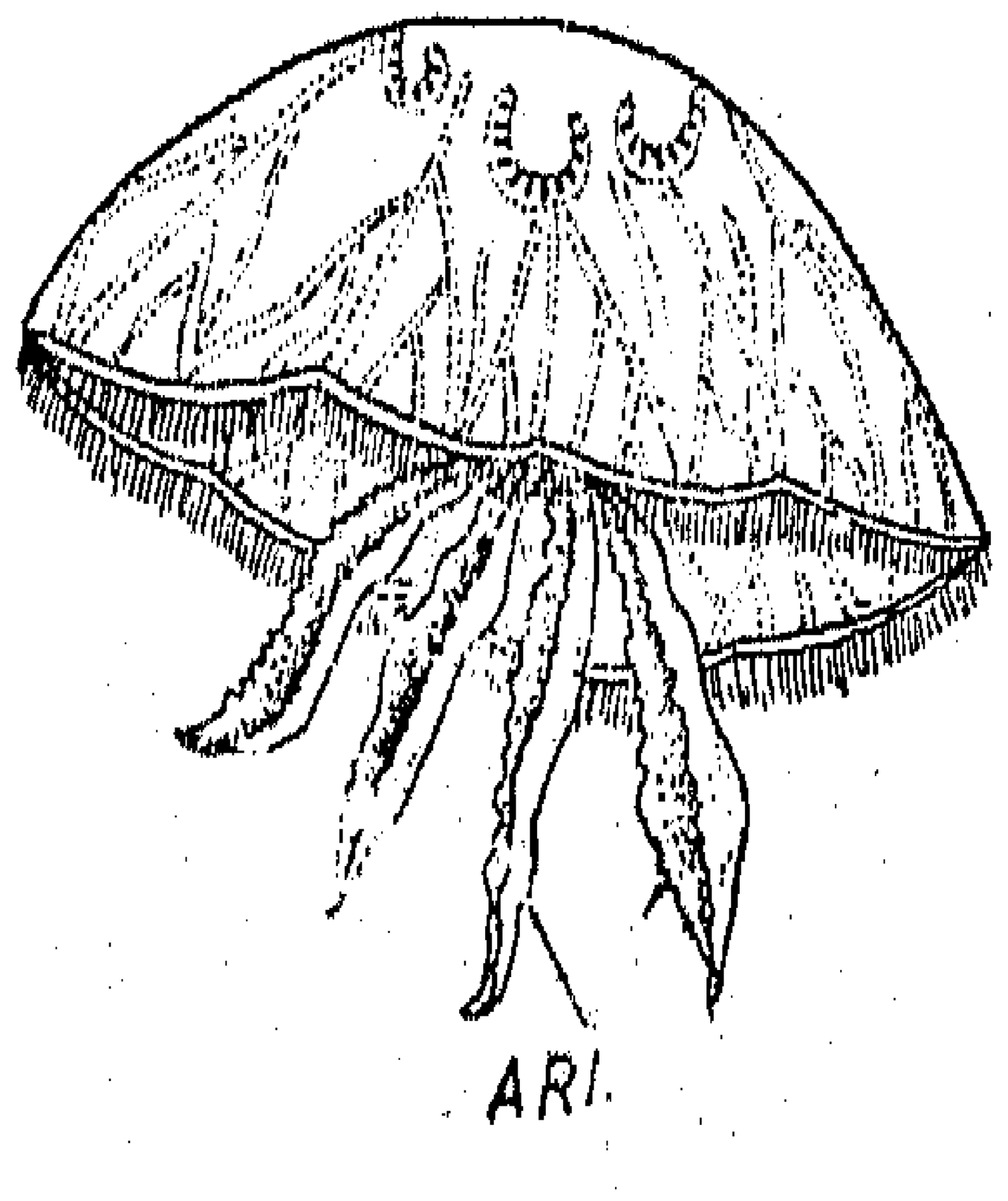

Fig. 17. *Aurelia*

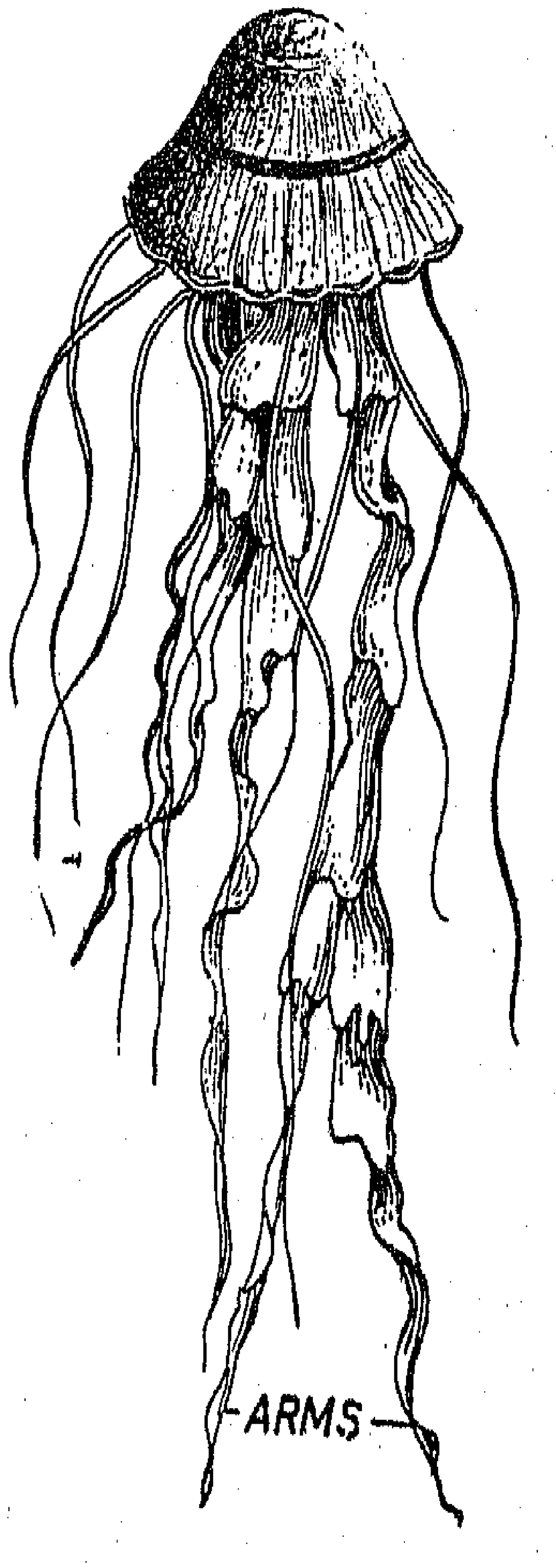

Fig. 18. *Jelly Fish*

between the asexual fixed stage (polyp) and the sexual free-swimming stage (medusa) is common; *e.g.*, Hydra, (Fig. 15), Obelia, (Fig. 16), Jelly fishes (Fig. 17, 18) Sea-anemone, Corals, Physalia (Fig. 19), etc.

Hydra. It is a solitary fresh-water polyp. It is tubular, with an anterior mouth surrounded by several (6-10) delicate tentacles, and is attached normally to aquatic plants (*e.g.*, Hydrilla) and rocks by an adhesive basal disc.

Jelly fish. (Aurelia aurita): It is a free-swimming medusa, which is umbrella-shaped, with an upper convex and lower concave surface, (Fig. 17) The margin is provided with minute tentacles. The concave surface bears the mouth in the centre which is surrounded by four tapering oral arms.

Sea-anemone. It has a cylindrical body and, like the hydra, is a polyp type. (Fig. 20) The upper flat oral surface, bearing the mouth, is surrounded by many short hollow tentacles. The tentacles bear a large number of stinging cells. The basal disc serves for attachment to solid objects like a rock. The gastro-vascular cavity is divided into numerous radial compartments by means of septa, which extend from the body wall.

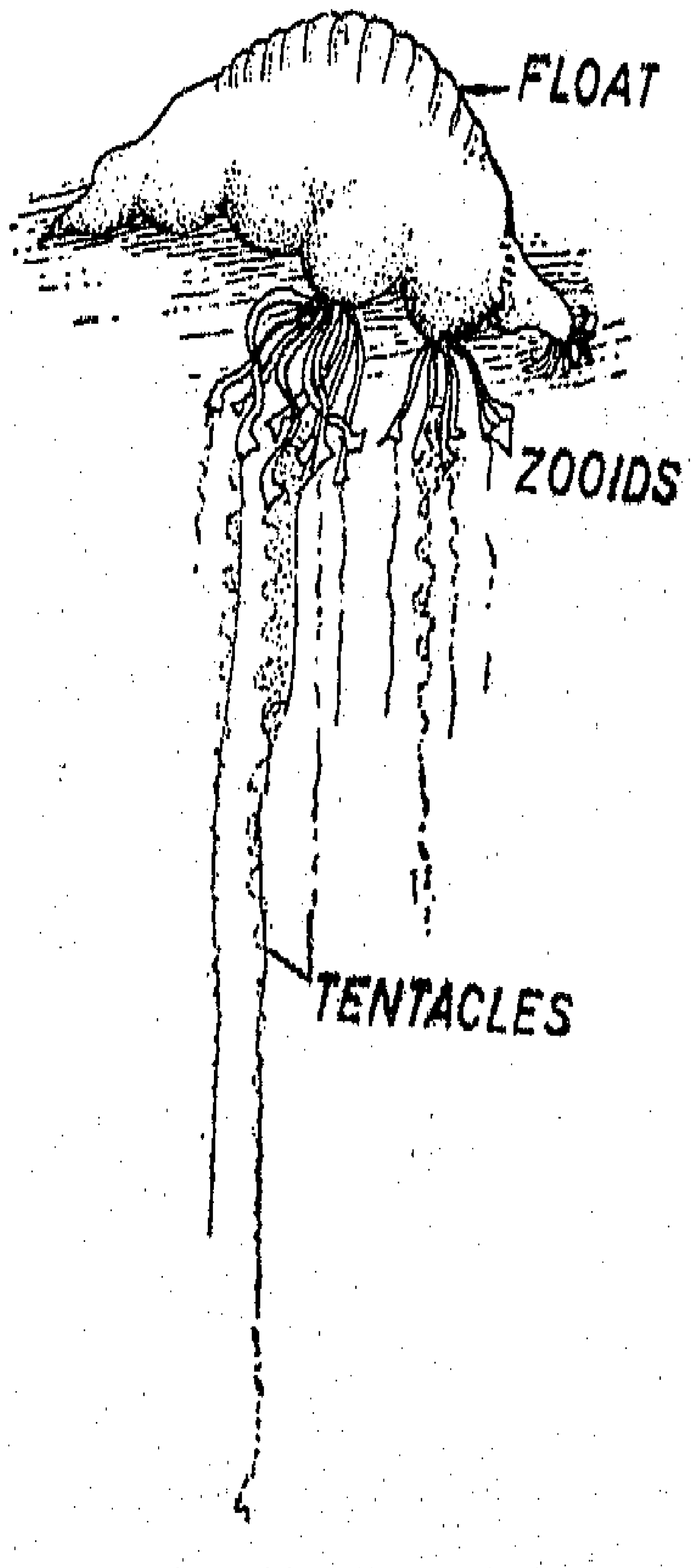

Fig. 19. *Physalia*

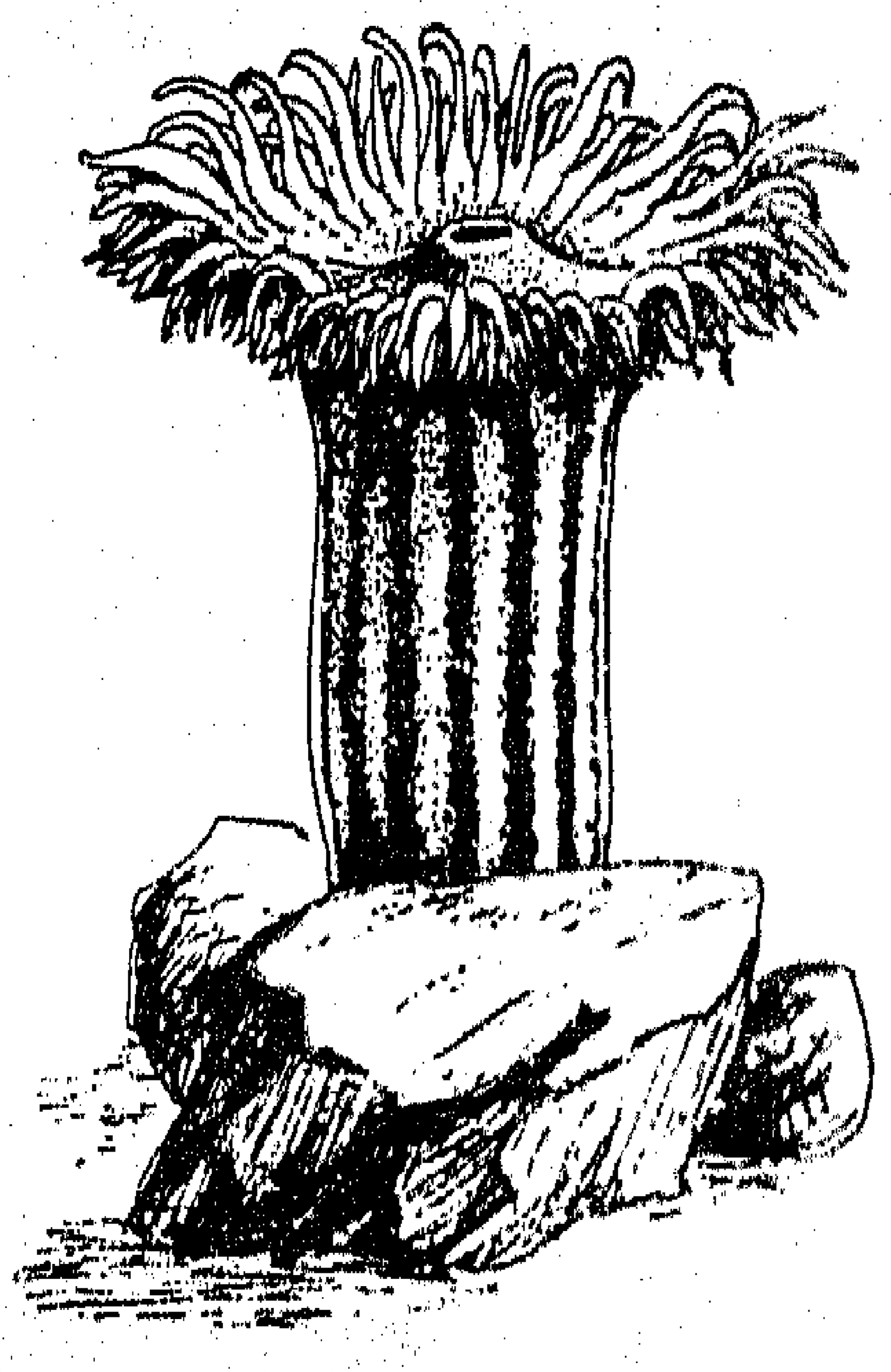

Fig. 20. *Sea anemone*

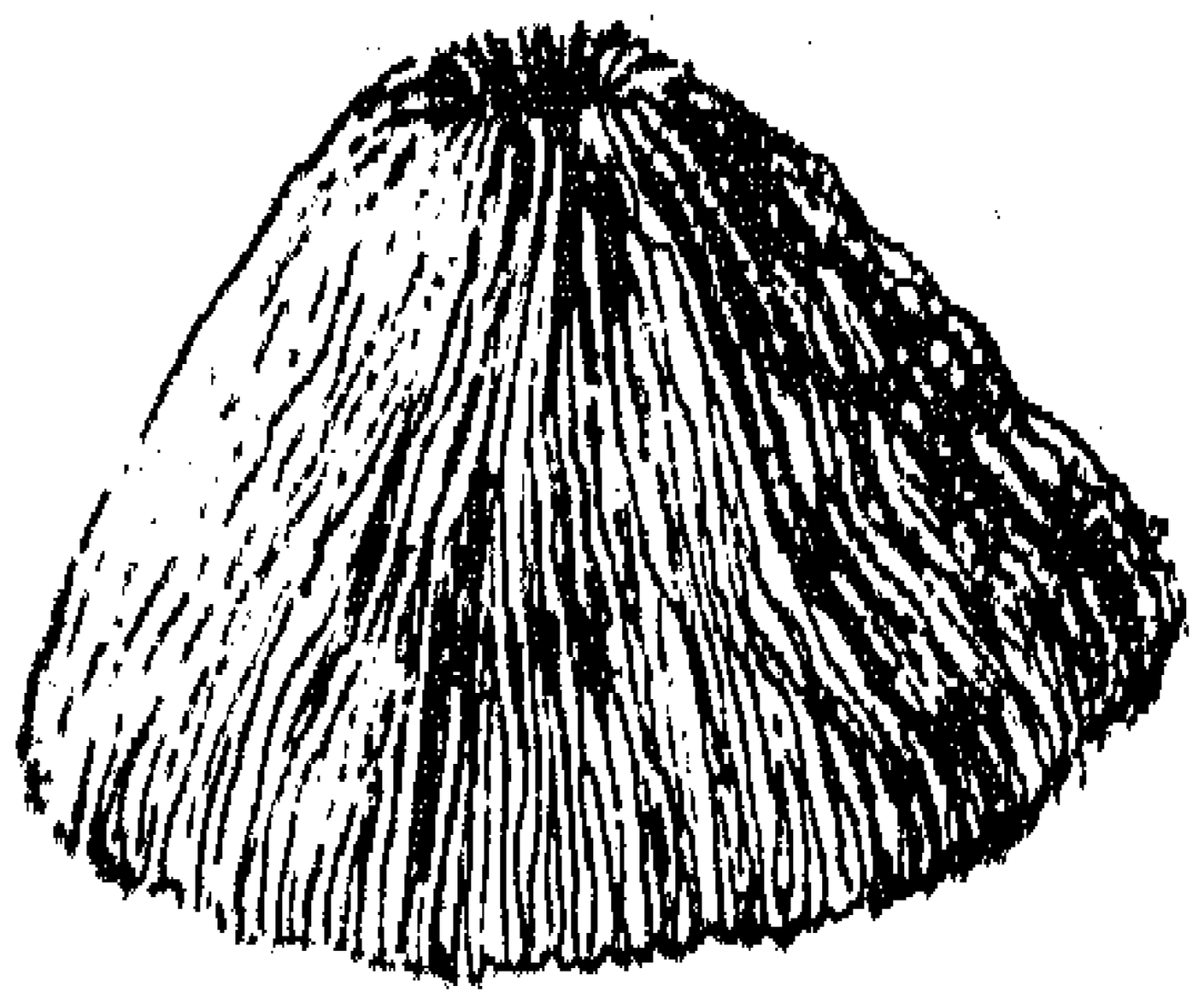

Fig. 21. *Fungia*

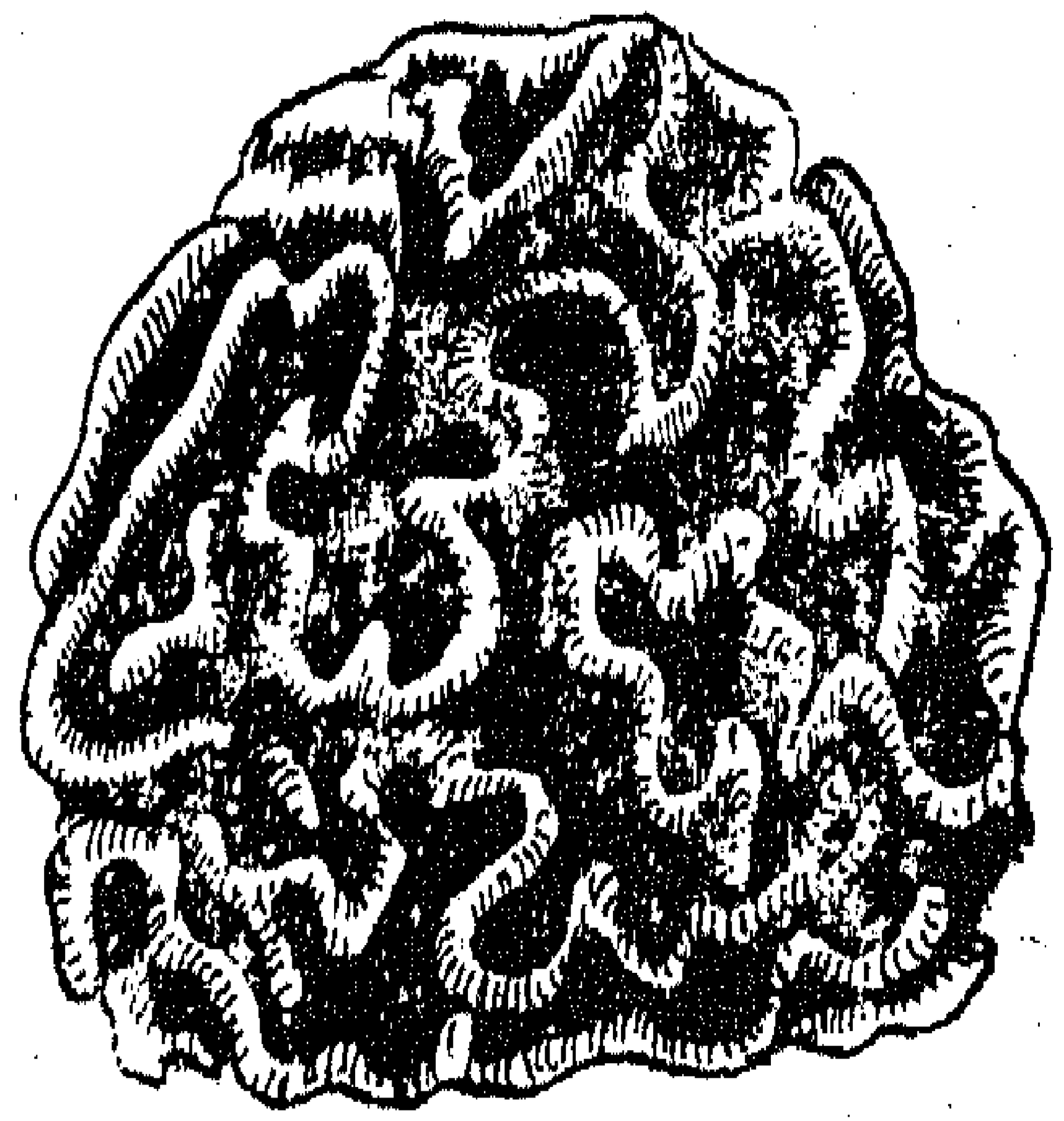

Fig. 22. *Brain coral*

Corals. The term coral is normally used for the hard calcarious skeleton secreted by the organisms that live in colonies. The individuals are small polyps with short tentacles, but without the basal disc. The ectodermal secretions of these individuals of the colonies produce the calcareous corals, coral reefs and coral islands found in many parts of the sea.

There are different types of corals, *e.g.*, Fungia (Mushroom-coral, Fig. 21) Madrepora, or the brain coral (Fig. 22), Tubipora (organ-pipe coral) and the Horny coral (gorgonia or sea fan).

Phylum-Platyhelminthes

This phylum includes the flat worms *e.g.*, the planarians, the liverflukes and the tape worms. The body is bilaterally symmetrical triploblastic, usually flattened dorso-ventrally. The body cavity or coelom is absent. The space between the internal organs is filled up by loose parenchymatous tissue. Neither the blood vascular system nor the respiratory system is present. The excretory system is formed of branched tubes, which end in characteristic flame cells. The digestive system is incomplete, with a mouth but without anus. The nervous system is present, and has a nerve ring, nerve ganglia and nerve cords. The reproductive system is well developed and complicated. These worms are mostly *hermaphrodite* (*i.e.*, both the male and the female reproductive organs are present in one and the same individual). Some of the animals are free living either in fresh water, salt water, or, less frequently, on land. Others are parasitic. Many of the parasitic forms pass through a number of complex intermediate developmental stages and live in the bodies of several species of animals during their life-history.

Planaria. They are fresh water and free-living flatworms, which are found under stones or logs in fresh water. (Fig. 23) They have a blunt triangular anterior end or "head" and a tapering posterior end. The head region bears two black eye-spots on the dorsal side. The mouth is ventral, near the middle of the body.

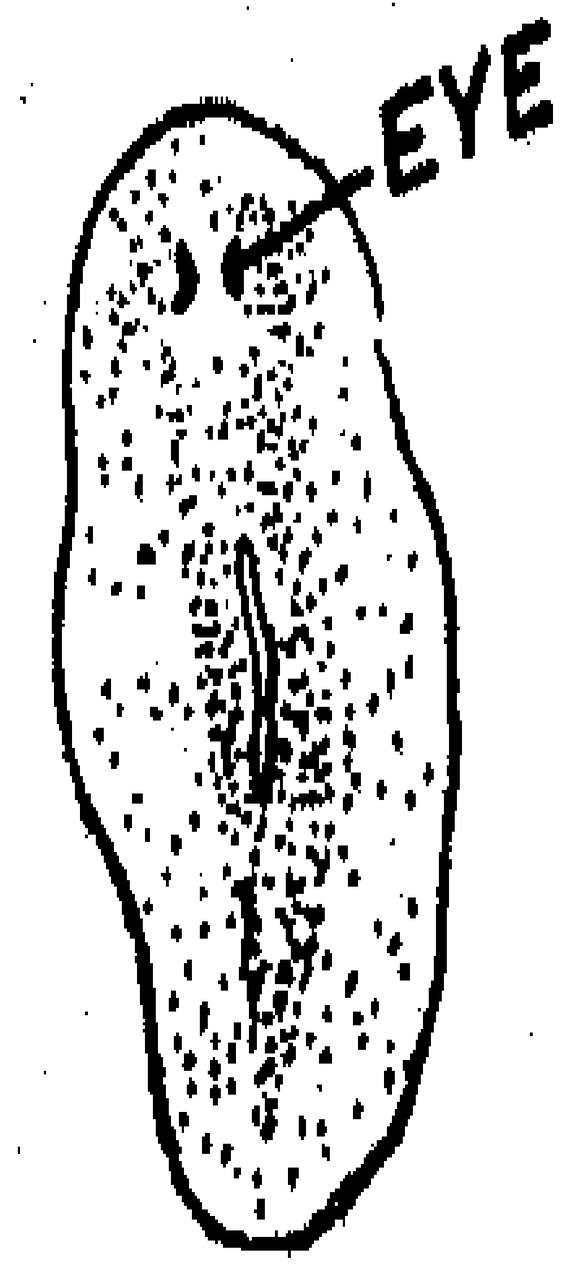

Fig. 23. *Planaria*

Liverfluke. (Fasciola hepatica). They are parasitic in the liver and bile ducts of sheep and cattle and sometimes in other mammals, and occasionally in man. (Fig.24) They produce the disease known as "liver rot". The liverfluke has a leaf-shaped body, rounded anteriorly and blunt posteriorly. There are two disc-shaped suckers for attachment to the host. One is anterior, which surrounds the mouth, and is terminal. The other sucker is slightly posterior and ventral and is known as ventral sucker. The reproductive system is well developed and the life cycle passes through two hosts, one invertebrate, *e.g.*, the snail, and the other, the vertebrate.

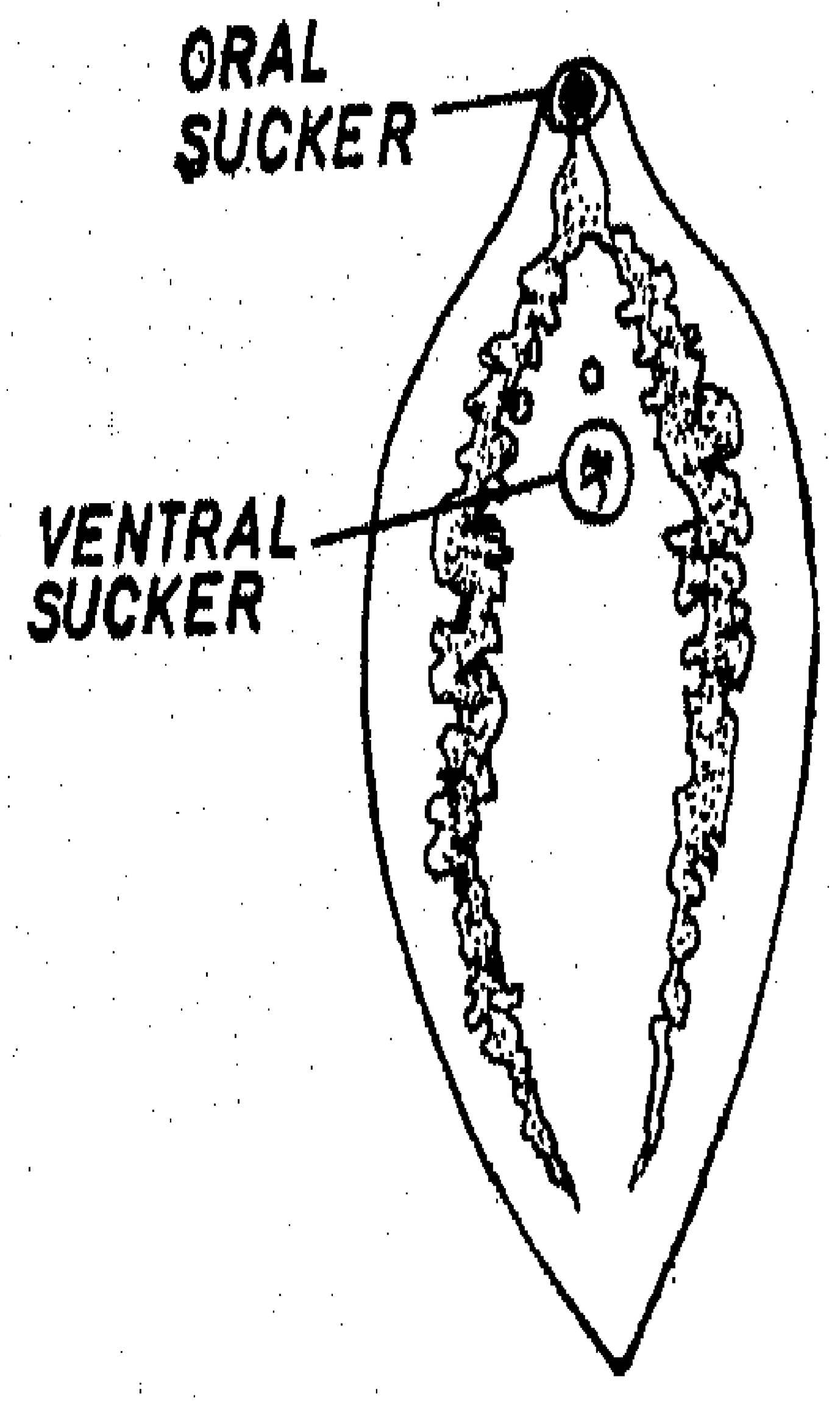

Fig. 24. *Liverfluke*

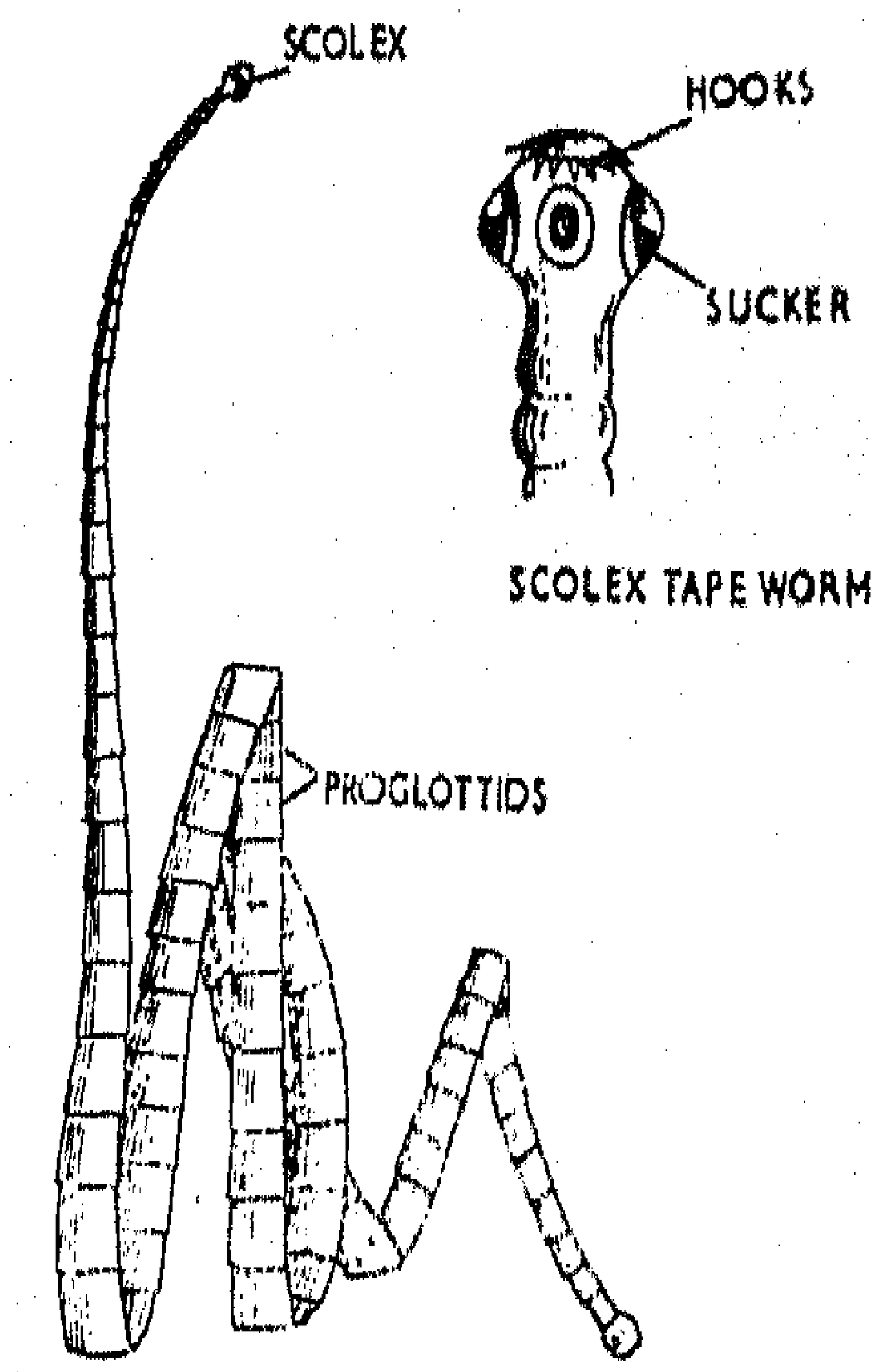

Fig. 25. *Tapeworm*

Tape worm (*Taenia solium*). Tape worms are parasitic in the digestive tracts of vertebrate animals, including man. They are long, flat, ribbon-like worms (Fig. 25), consisting of chains of false segments called *proglottids* which bud off from a small knob-like head or *scolex*, which is attached to the intestinal wall of the host. Proglottids have a complete set of both male and female reproductive organs.

Phylum-Nemathelminthes (Nematoda)

These are unsegmented round worms. They are triploblastic and bilaterally symmetrical. The body is long, cylindrical, tapering at both ends. The surface of the body is covered with a thick cutile, which is smooth and shining. Since there is no epithelial lining for the body cavity, it is called pseudocoele. There is a complete alimentary canal which is a straight tube with a mouth and an anus at the two extremities of the body. The excretory system is simple. The circulatory and the respiratory systems are absent. The nervous system is in the form of a nerve ring surrounding the oesophagus and a few longitudinal nerve cords arising from it. Sexes are usually separate.

Many of the nematodes are parasitic in animals and cause serious diseases. Some infest plant tissue. Others are free-living, and are found in all sorts of situations, in water or soil; *e.g.*, Ascaris, Hook worms (Ancylostoma), Filarial worm (Wucheria bancrofti), Guinea worm (Dracunculus) and the Trichinella spiralis.

Ascaris. It is a common intestinal parasite found in man, monkey and pig. It measures from 5-11 inches in length. (Fig. 26) The animal is translucent in appearance. The cuticle is smooth and marked with fine striations. The mouth is at the anterior end and is surrounded by dorsal and ventral lips, which are finely toothed and bear papillae. The anal opening is at the posterior end from which, in the male, extend two penial setae, used during

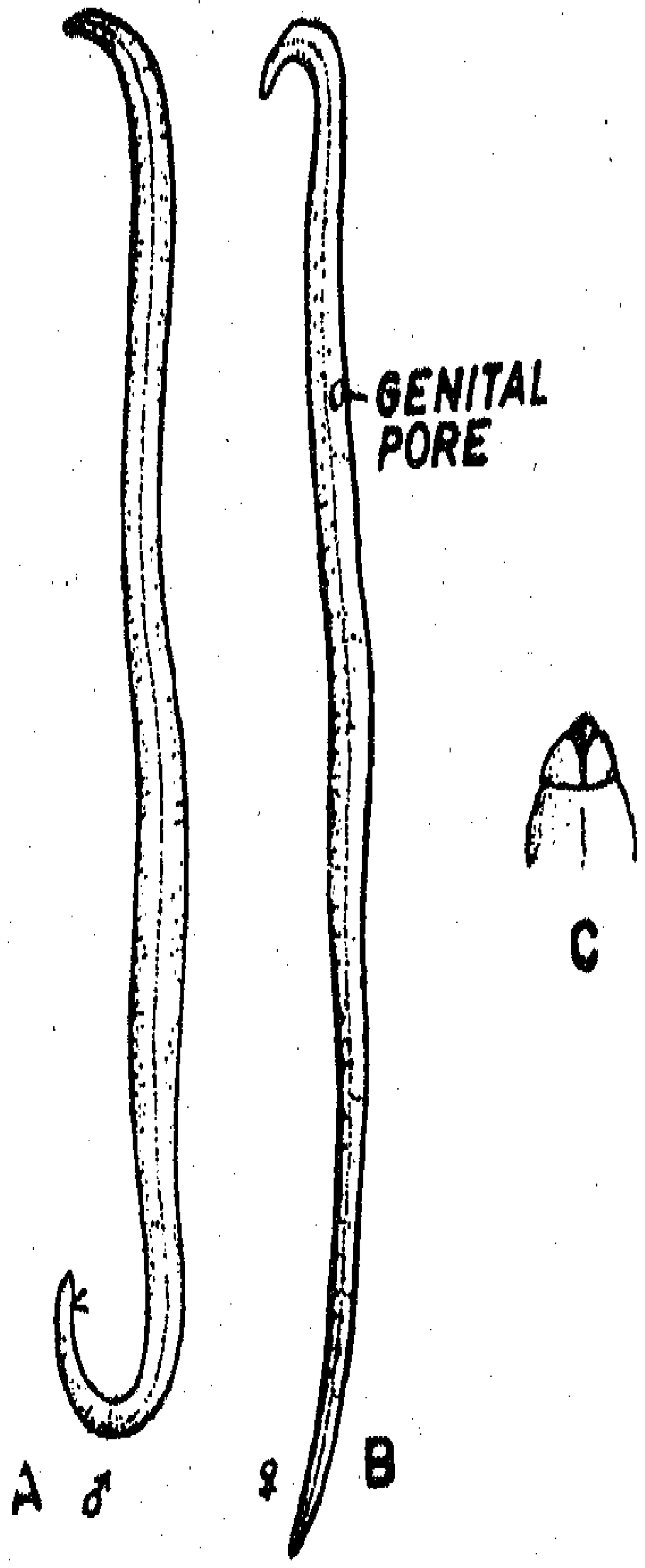

Fig. 26. *Ascaris*
A. Male; B. Female
C. Anterior end (magnified)

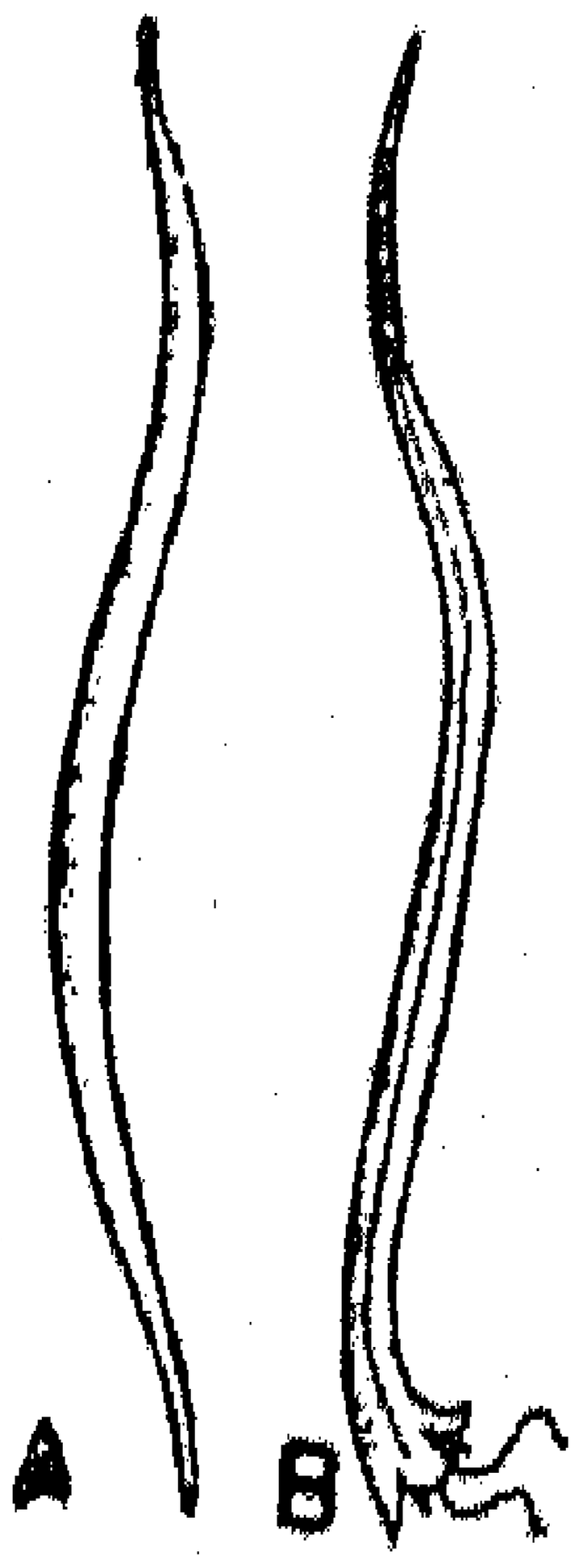

Fig. 27. *Hook Worm*
A. Male; B. Female

copulation. The male is distinguished from the female by the presence of a bend in the posterior part of the body and the presence of penial setae.

Hook worm (Ancylostoma). They are intestinal parasites of man. (Fig. 27) Their larvae enter the body through the skin of the feet, get into the blood and then reach the lungs and ultimately the intestine. They produce an anaemic condition in the host.

Trichina worm (Trichinella spiralis). They are parasitic in the muscles of man, pig and dog, and cause the disease known as Trichinosis.

Filaria-worm (Wucheria bancrofti). It causes elephantiasis in man by clogging the lymph passages whereby the limbs or other

parts grow to enormous size. Minute larvae are taken up by a certain kind of mosquitoes (Culex) and are transmitted to human subjects by their bite.

Guinea worm (Dracunculus medinensis). It causes a disease in man, commonly called "Naru" or *Dracunculosis*. It causes abcesses under the skin in the arm, ankle, foot and shoulders. The worm is thread-like and is as long as 3 feet. Young larvae are discharged from the worm and escape through an opening in the human skin. If they reach water, they infest fresh-water fleas (Cyclops—Fig. 34), where they metamorphose. Man becomes infested by swallowing the infested cyclops through drinking water.

Phylum-Annelida

These are referred to as the true worms, as distinguished from the platyhelminthes and the nemathelminthes. The annelids are triploblastic, bilaterally symmetrical animals. They have an elongated body, which is divided into a large number of similar parts called segments (somites). Segmentation is both external as well as internal. Since most of the organs are repeated in all the segments, segmentation is referred to as *metameric*, and the segments are called as *metameres* or somites. The body cavity (*i.e.*, the space between the outer body wall and the internal organs) is a true *coelom*. The digestive tract is complete with mouth and anus. The circulatory system is of the closed type, since the circulating fluid is confined within the heart and blood vessels. The respiratory pigment – Haemoglobin—is dissolved in the plasma. The excretory organs are *nephridia*, which occur in large numbers in most segments. Respiration takes place through the skin or in some by gills. The nervous system consists of a solid double ventral ganglionated nerve cord, connected to a pair of ganglia (Brain), situated dorsal to the pharynx by a nerve ring.

There is a ganglionic swelling in each segment on the cord. Chitinous spiny bristles, known as *setae* or chaetae, projecting from the body wall, are used in locomotion. Sexes are usually united and hence they are hermaphrodite. Some of them reproduce asexually by budding. Many of them have the power of *regeneration*, when cut into pieces.

Some animals are free-living in soil, fresh water or in salt water. Certain others, like the leech, are parasitic, *e.g.*, Earthworm, Nereis, Leech.

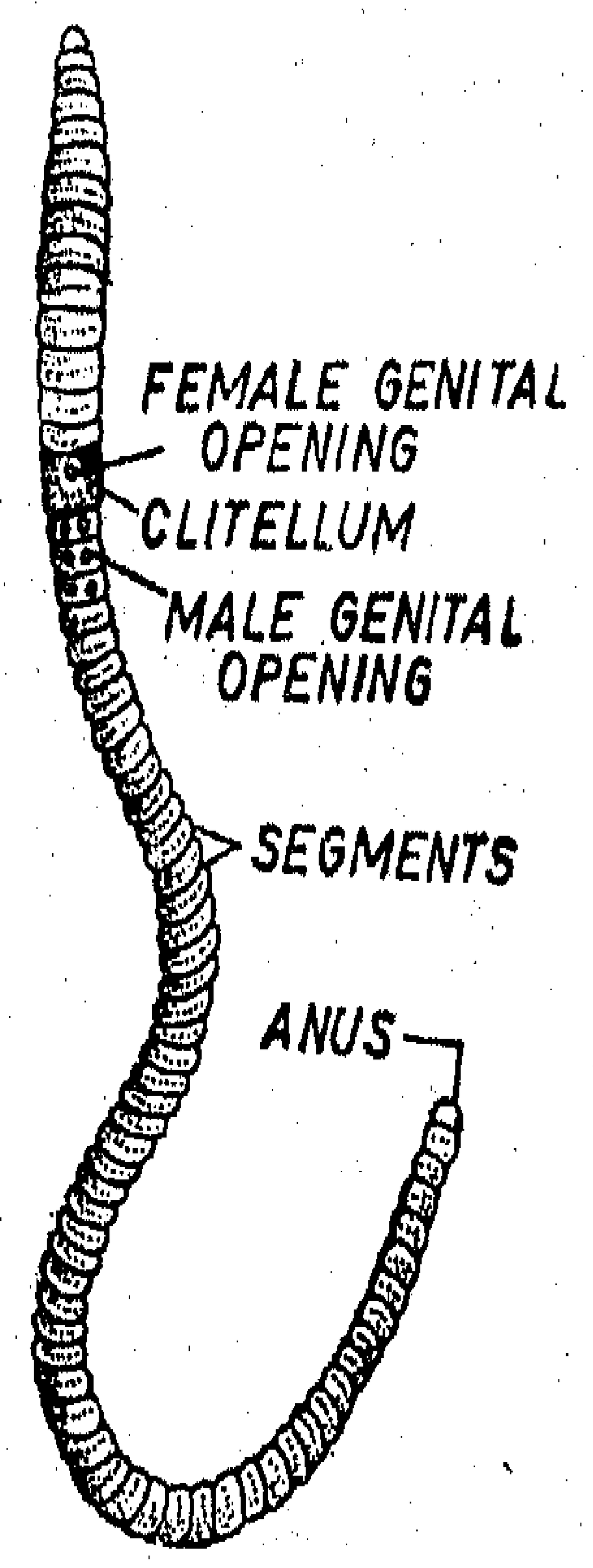

Fig. 28. *Earthworm*

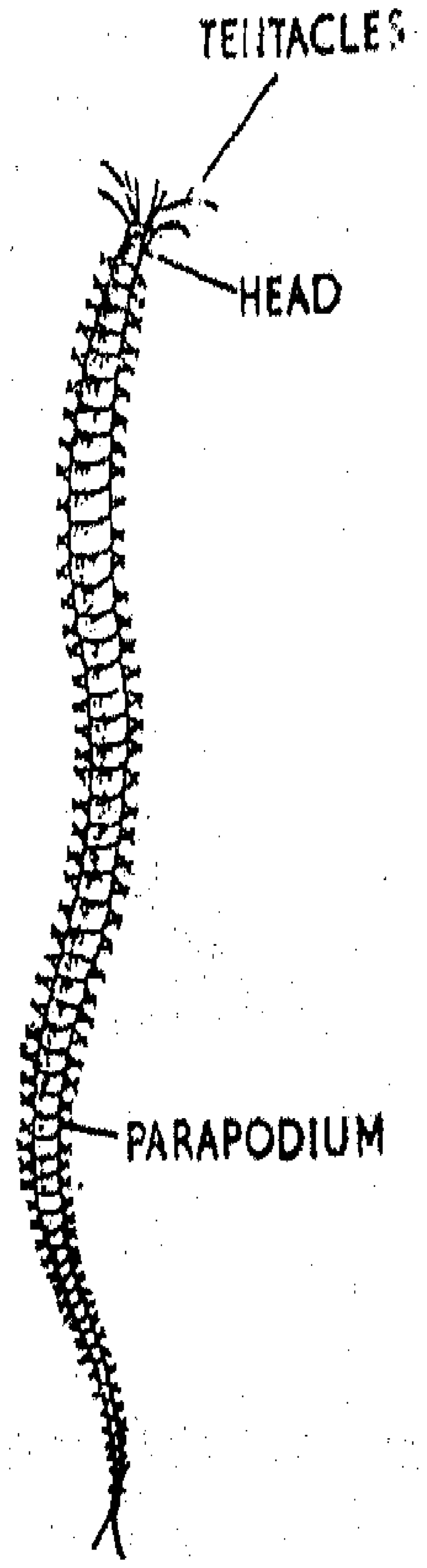

Fig. 29. *Nereis*

Earthworm (Fig. 28). They are mostly found in damp soil amongst decaying vegetation, and they are normally found burrowing in the soil. Earthworms are very useful to the farmer because of the fact that they bring out the more fertile soil of the lower layers to the upper surface. In this process, they also loosen the soil and bring about its aeration. They swallow large quantities of earth; and, after having taken all the nutrition from it, the earth is thrown out in the form of characteristic castings. The body is cylindrical and divided into a large number of segments (120-125). The setae are arranged in the middle of each segment in the form of rings, except in the first and the last segments. The mouth and the anus are terminal. In the region of the 14th, 15th and the 16th segments, the integument is highly glandular and the segments are fused externally to form a thick band or belt-like structure called *clitellum*. This region secretes a chitinous egg case or *cocoon*. The animal is hermaphrodite, *i.e.*, bisexual. Self-fertilization is avoided because of the different timings in maturity of the male and the female organs.

Nereis. They are marine and found burrowed in sand or under the stones. (Fig. 29) The body is elongated and segmented. There is a distinct head bearing tentacles and two pairs of eye-spots. Each body segment or somite has a pair of lateral processes called *parapodia* (singular, *parapodium*) which bear setae. They are used as organs of locomotion, for creeping in sand and also for swimming.

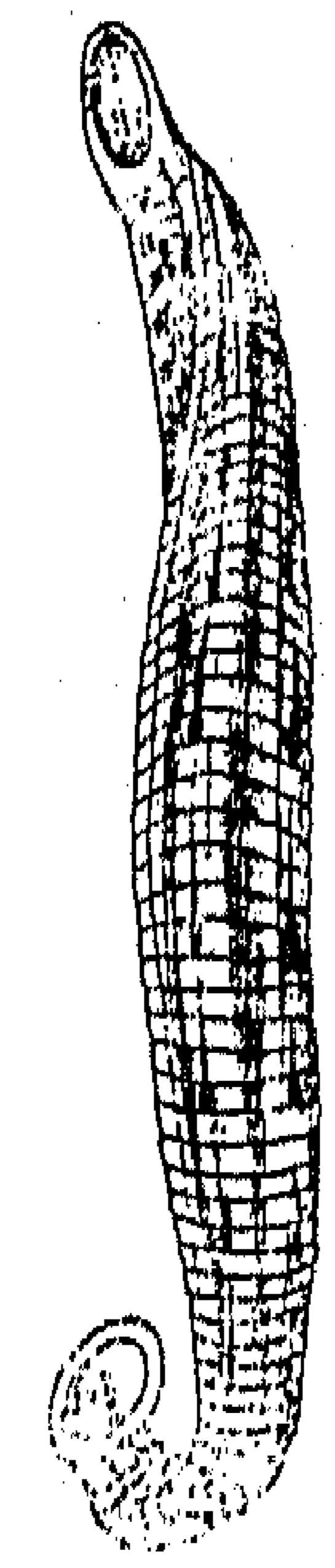

Fig. 30. *Leech*

Leech. Most of them live in fresh water, though some of them are marine and a few live on moist land. (Fig. 30) Some of them are blood-sucking ectoparasites on animals such as fishes, reptiles and mammals, including man.

Leeches are dorso-ventrally flattened and segmented. The segments are in definite number (30-35). There are two suckers, one at either end of the body, which are used for attachment and locomotion. The mouth in the centre of the anterior sucker, and is provided with 3 semicircular chitinous jaws. The anus is dorsally placed at the base of the posterior sucker. The digestive tract of the leech is provided with side pouches which store the blood that the leech sucks from its hosts.

The common medicinal leech (Hirudo) is of interest in that it is used by some to suck the blood from the inflamed parts. It makes the incision on the body of its prey and the blood is sucked into the gut. The saliva secreted by it contains an anticoagulant, *Hirudin*, which prevents the blood from clotting during sucking. The blood that it stored is sufficient for it for 4-5 months.

Phylum-Arthropoda

Arthropoda comprises the largest phylum in the animal kingdom, in so far as the number of species is concerned, which surpasses the total number of species of all the rest of phyla put together. They inhabit all the possible habitats that support life.

They live in oceans, fresh water lakes, ponds and rivers. They are also found on land. Some are parasitic on animals ; and many of them lead an aerial life. Arthropods are economically important to man as some of them form food, some convey diseases and yet others are pests which destroy valuable food crops.

They are tripoblastic, bilaterally symmetrical, segmented animals. The segments are variously fused so as to give rise to different regions of the body such as head, thorax and abdomen. The segments, all or some, bear a pair of jointed appendages *Arthron—joint* ; *podus—foot*). The head bears sense organs like the antennae and the eyes. The body is covered with an external skeleton (exoskeleton) of their chitin only or chitin impregnated with **calcium** salts. This exoskeleton is cast out at intervals (Ecdysis) **and a new** one is formed as the animal grows. This skeleton is flexible at places to provide movable joints. The digestive tract is complete and divisible into fore-, mid-, and hind-gut. The mouth has lateral jaws (mandibles).

Respiration is by gills, tracheae (ectodermal air tubes), book lungs or through the body surface, depending upon the habitat of the animal. The body cavity *i.e.*, the coelom, is much reduced and is confined to the cavities of the gonads. The rest of the body space is called *haemocoele*, for it is filled with blood. The blood vascular system is of an open type, with a dorsal heart having valvular openings, the *ostia*. Excretion is by *green glands* (antennary glands) or by *Malpighian tubules* which open into the gut. The nervous system consists of a pair of dorsal or cerebral ganglia or brain, connected by connectives to a ventral double ganglionated nerve cord. The sensory organs are the antennae, sensory (tactile) hair on the surface of the body, simple eyes (ocelli) or compound eyes, auditory organs (as in insects) and a statocyst (balancing organ).

The sexes are usually separate. Development may be direct or through metamorphosis, involving intermediate stages like larva and pupa.

The arthropoda includes various forms like crabs, lobsters, crayfish, prawns, shrimps, centipedes, millipedes, insects, scorpions, spiders, and mites.

Since it includes animals of varied nature, it is necessary to study some of the classes of the phylum-Arthropoda to which they belong.

Class—Crustacea

These are aquatic arthropods which breathe by means of gills. The head and thorax are fused to form a *cephalothorax* The exoskeleton is of chitin impregnated with calcium salts. The head bears two pairs of antennae (feelers) and a pair of compound eyes. Respiration mainly by gills. The balancing and hearing organ is a pair of statocysts.

The excretory organ is a pair of antennary or green glands ; *e.g.*, Lobster (Fig. 31), Crab, Prawn (Fig. 32). Cyclops (Fig. 34).

Lobster. It is found amongst rocks in the sea. The body is enclosed in an exoskeleton of chitin impregnated with calcium

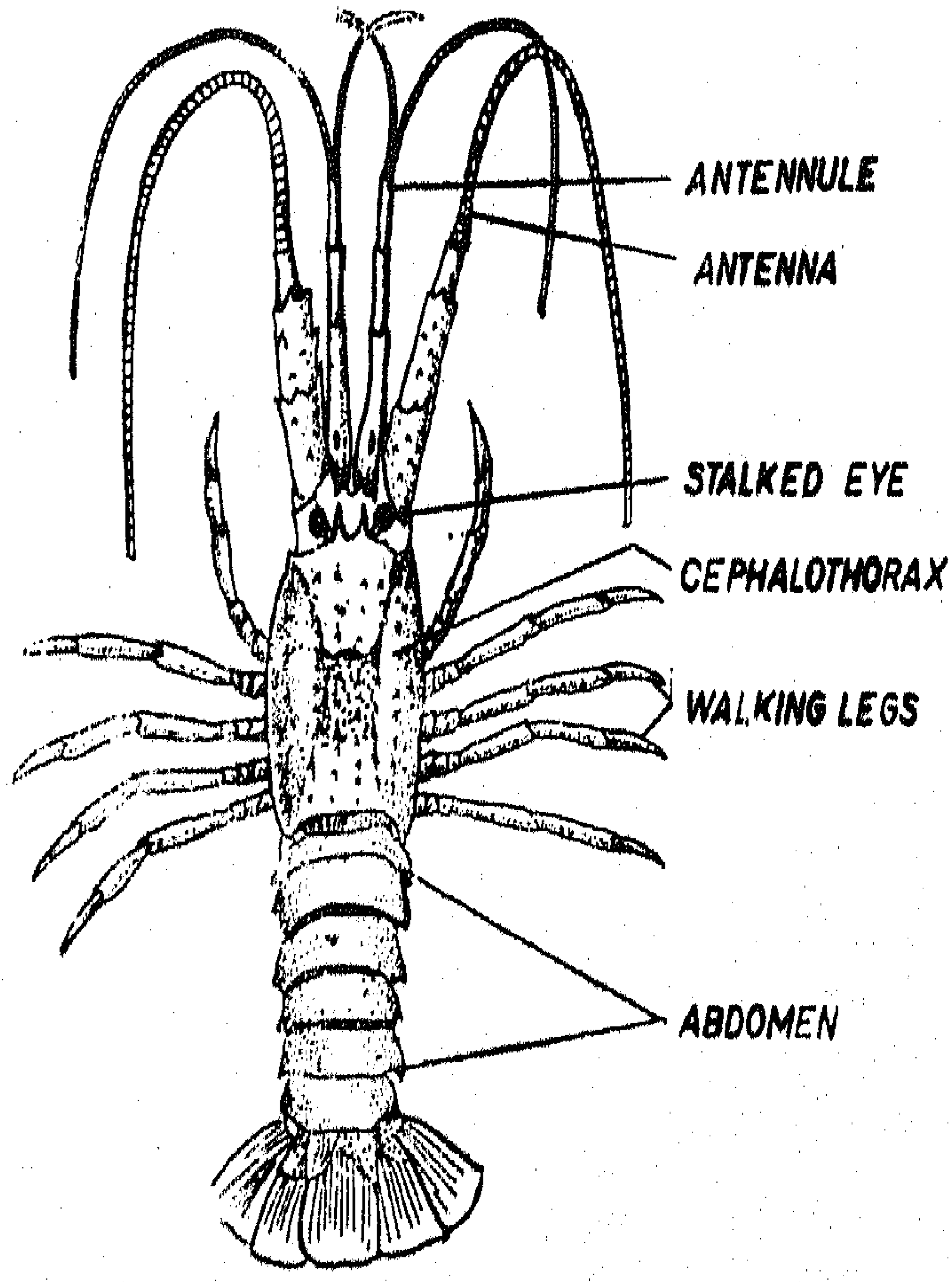

Fig. 31. *Lobster*

salts. The body is divisible into an anterior cephalothorax, which is formed by the fusion of the head and the thorax, and a posterior segmented abdomen. The head region bears a pair of antennules, a pair of antennae and a pair of stalked eyes. The thoracic region bears five pairs of walking legs. The segmented abdomen bears 4 pairs of swimming appendages (pleopods). The last abdominal segment has a tail-fin, formed of a telson and an uropod on either side. The mouth is at the anterior end and is provided with a pair

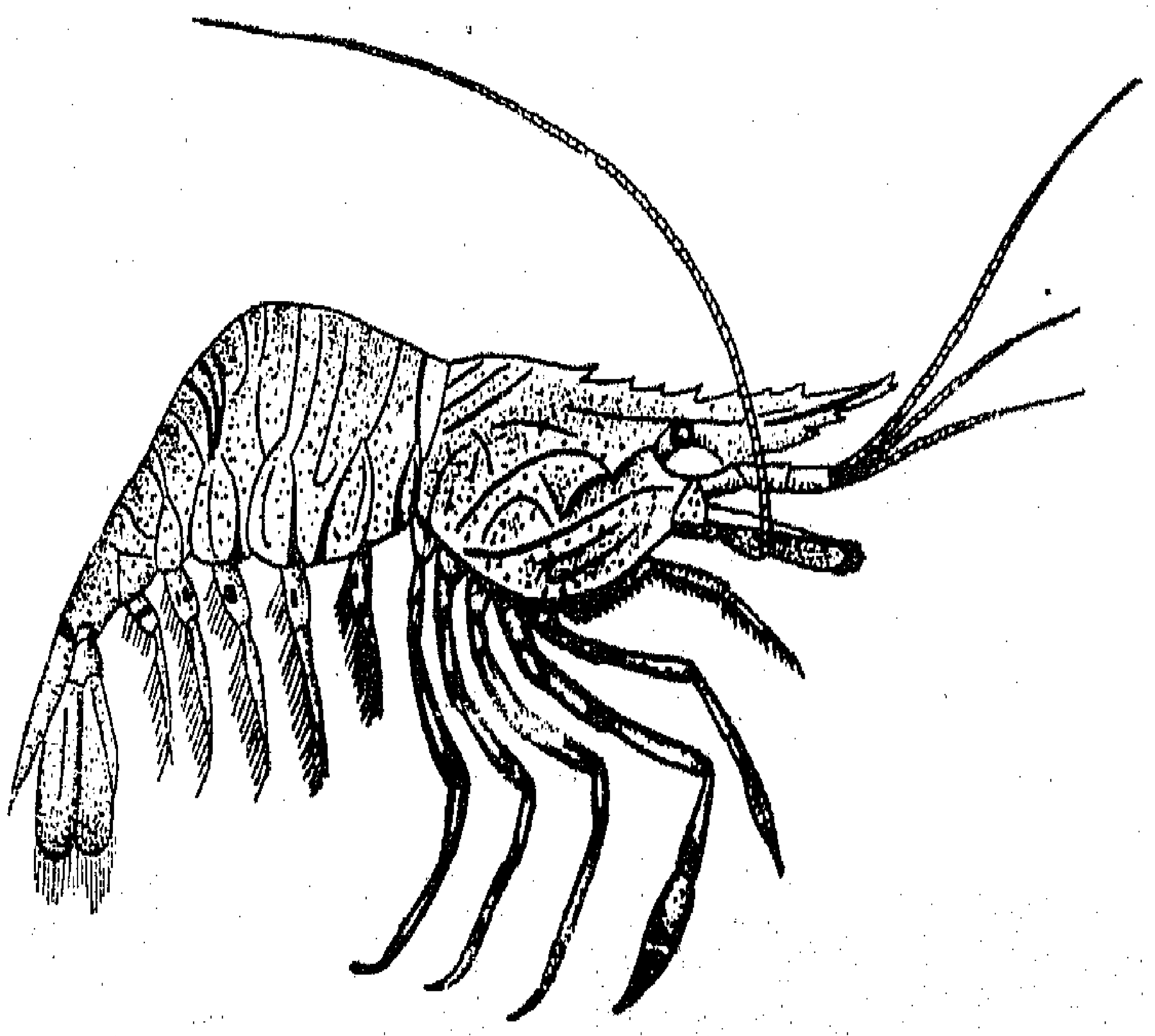

Fig. 32. *Prawn*

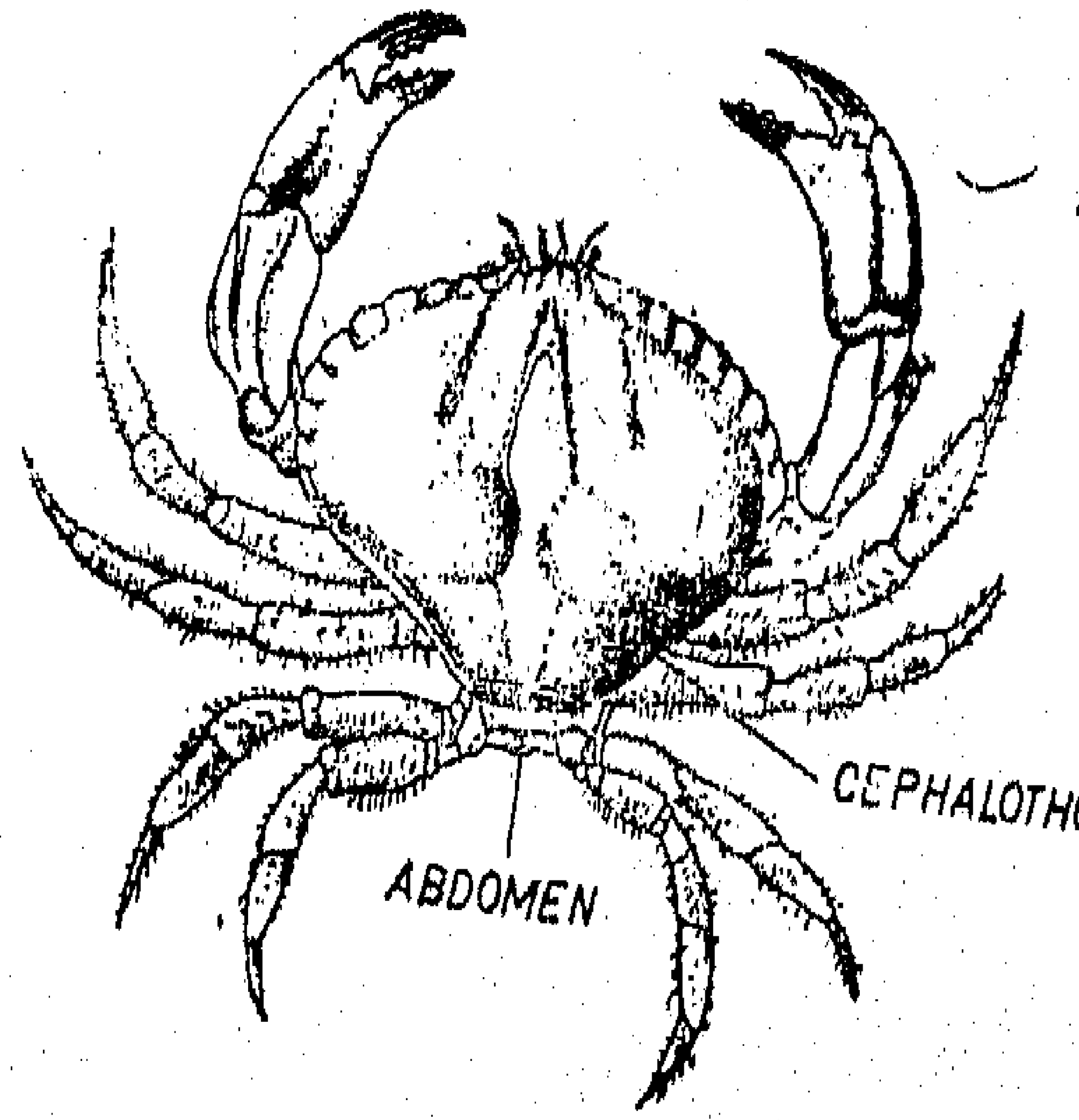

Fig. 33. *Crab*

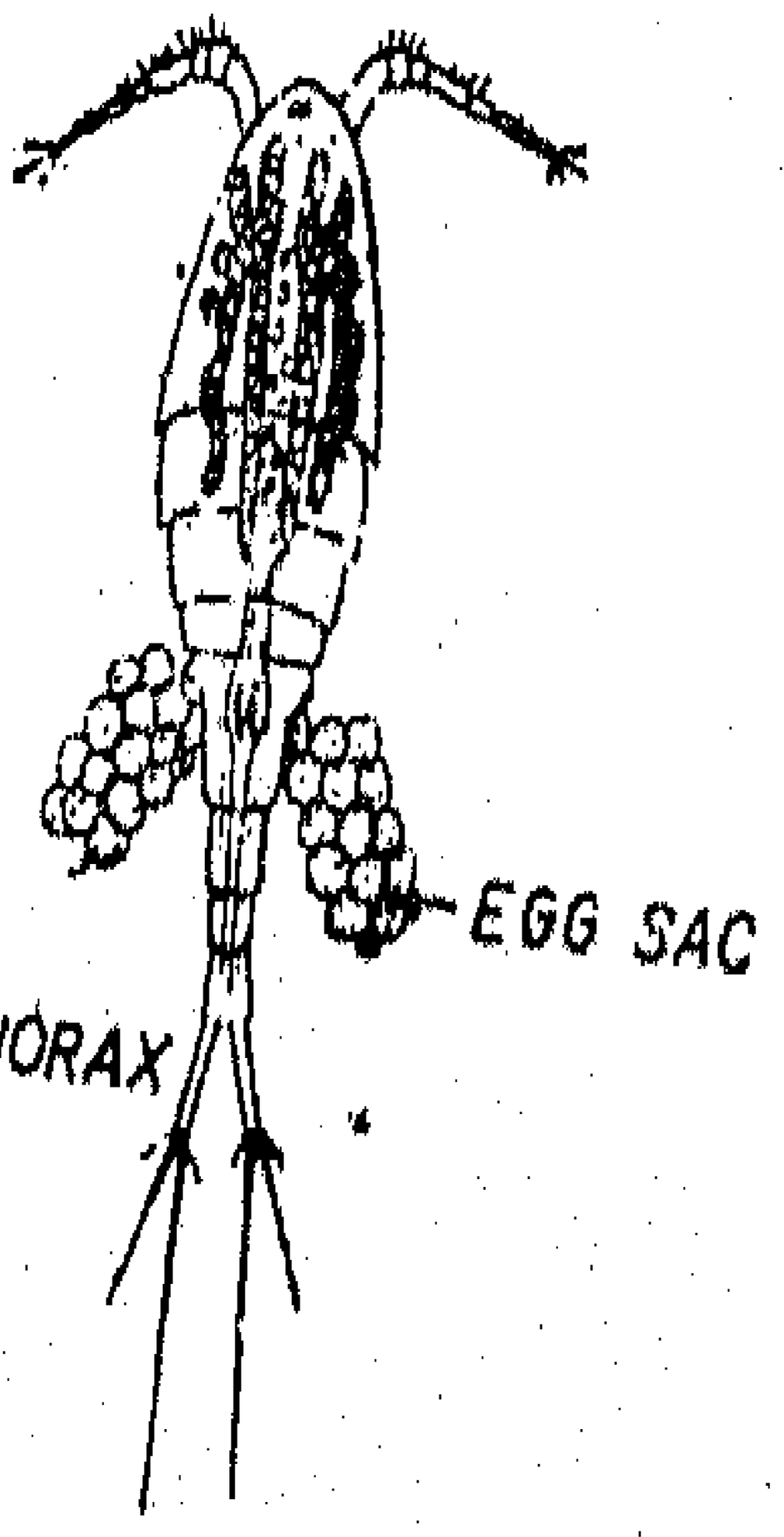

Fig. 34. *Cyclops*

of mandibles. The lobster normally swims backwards with the help of the pleopods, the tail-fin and the sudden flexion of the abdomen. It can also crawl on the substratum.

Carb. The body is divisible into a large cephalothorax and much reduced bent abdomen. (Fig. 33). The first pair of walking legs is modified to form *pincers* or *chela.*

Class—Insecta

These are arthropods whose body is divisible into head, thorax and abdomen. The head bears a pair of antennae and a pair of compound eyes. The mouth parts are of the chewing piercing or and is of sucking type. The thorax is made up of three segments,

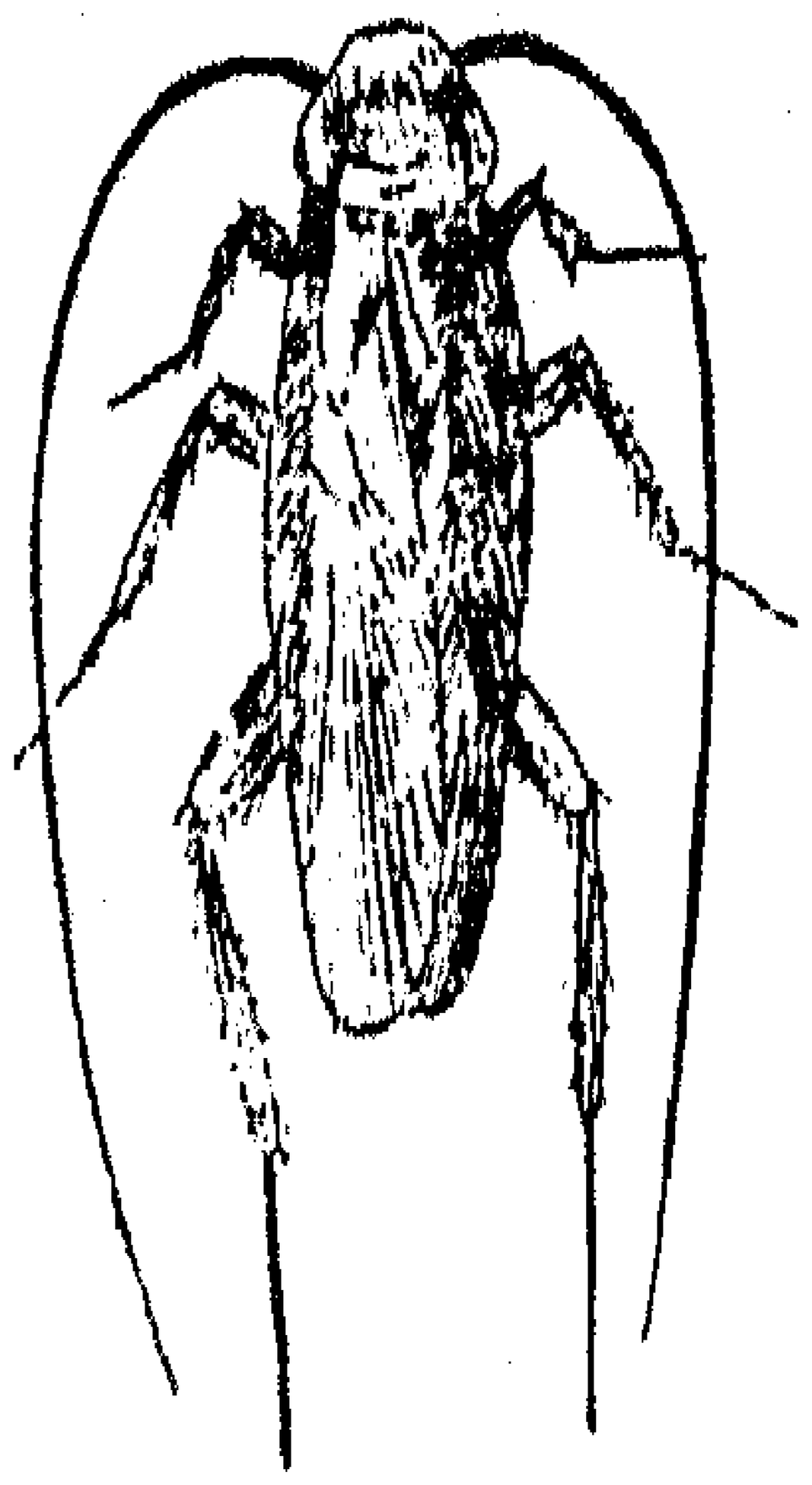

Fig. 35. *Cockroach*

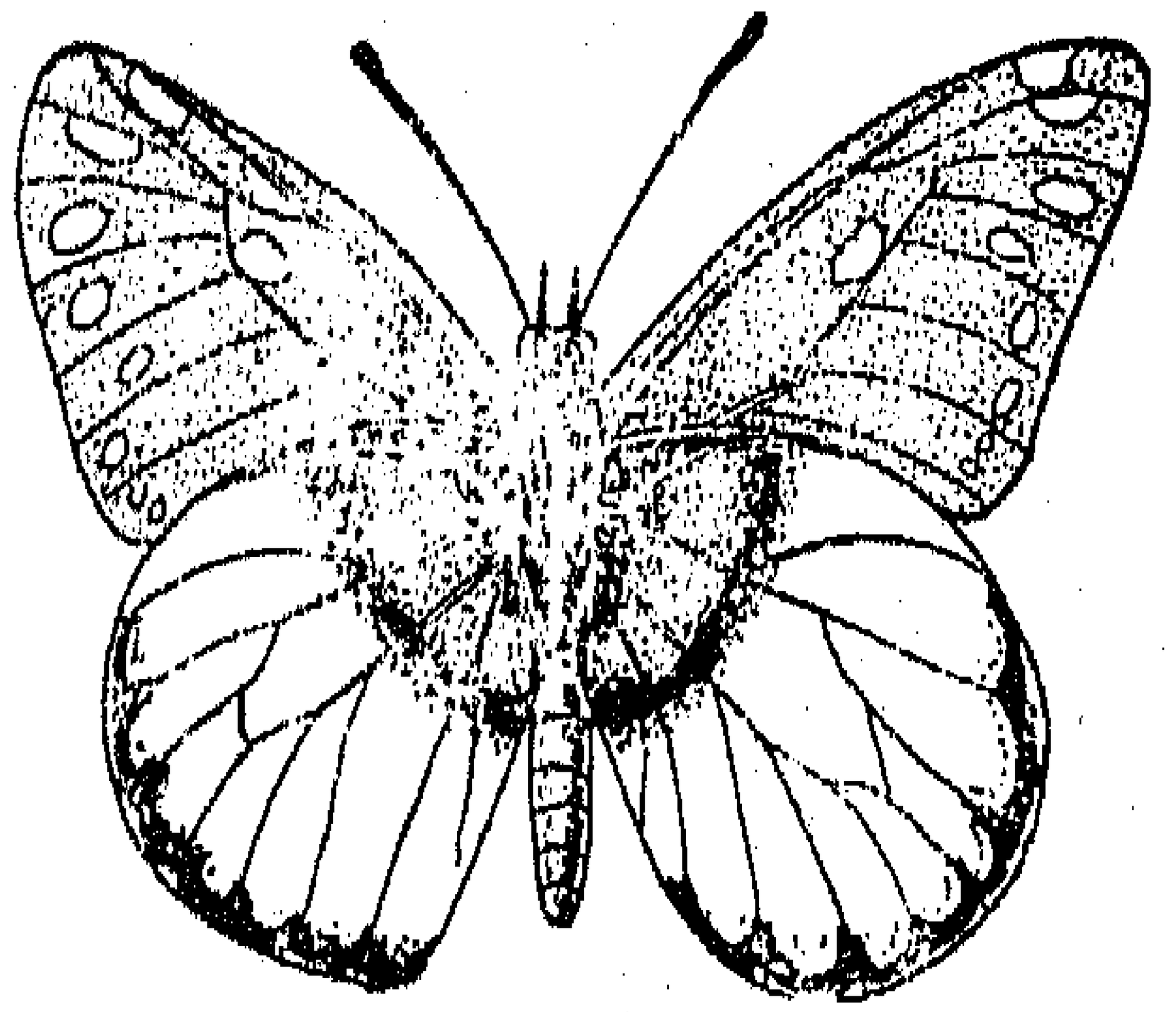

Fig. 37. *Butterfly*

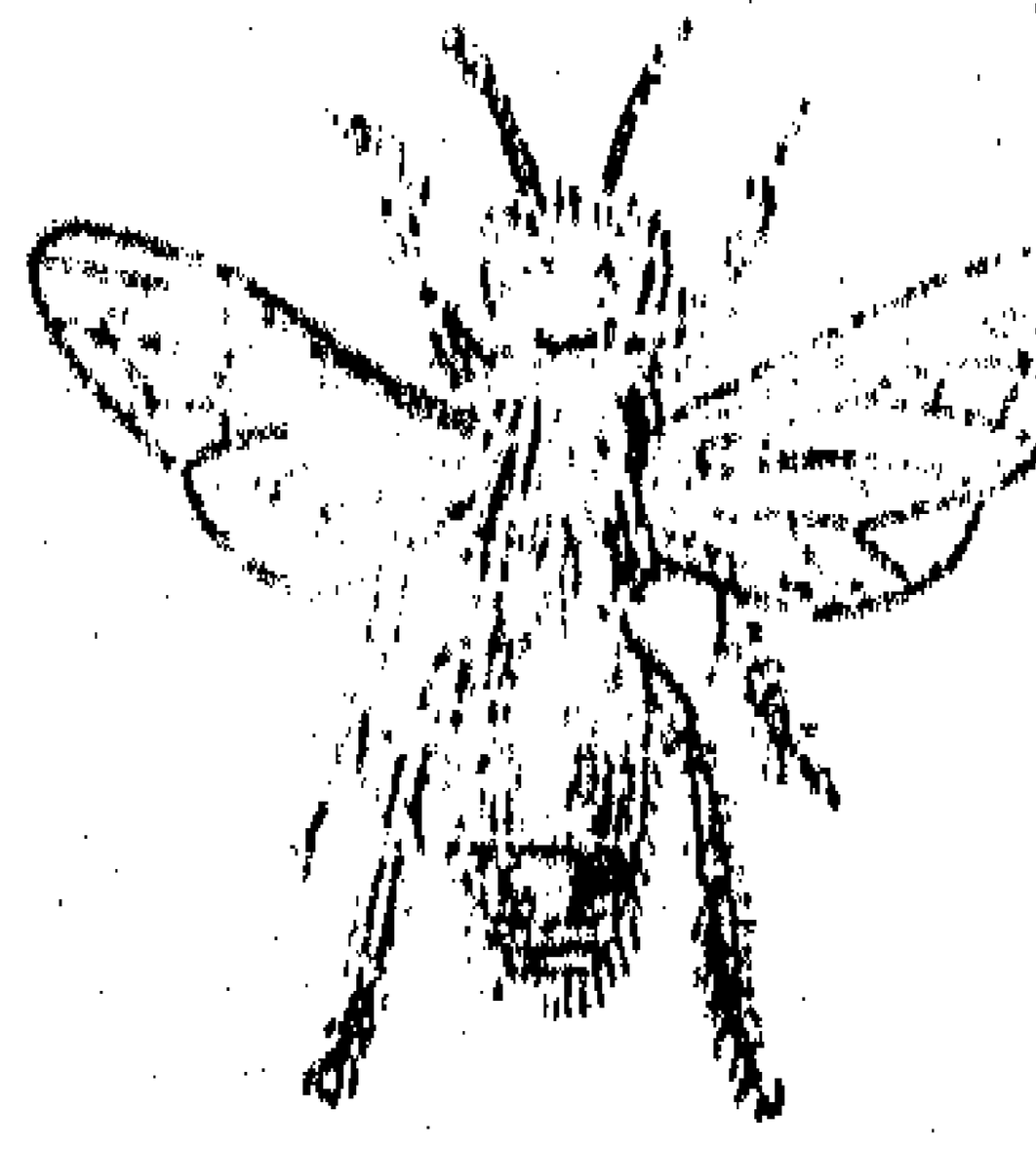

Fig. 36. *Honey-bee*

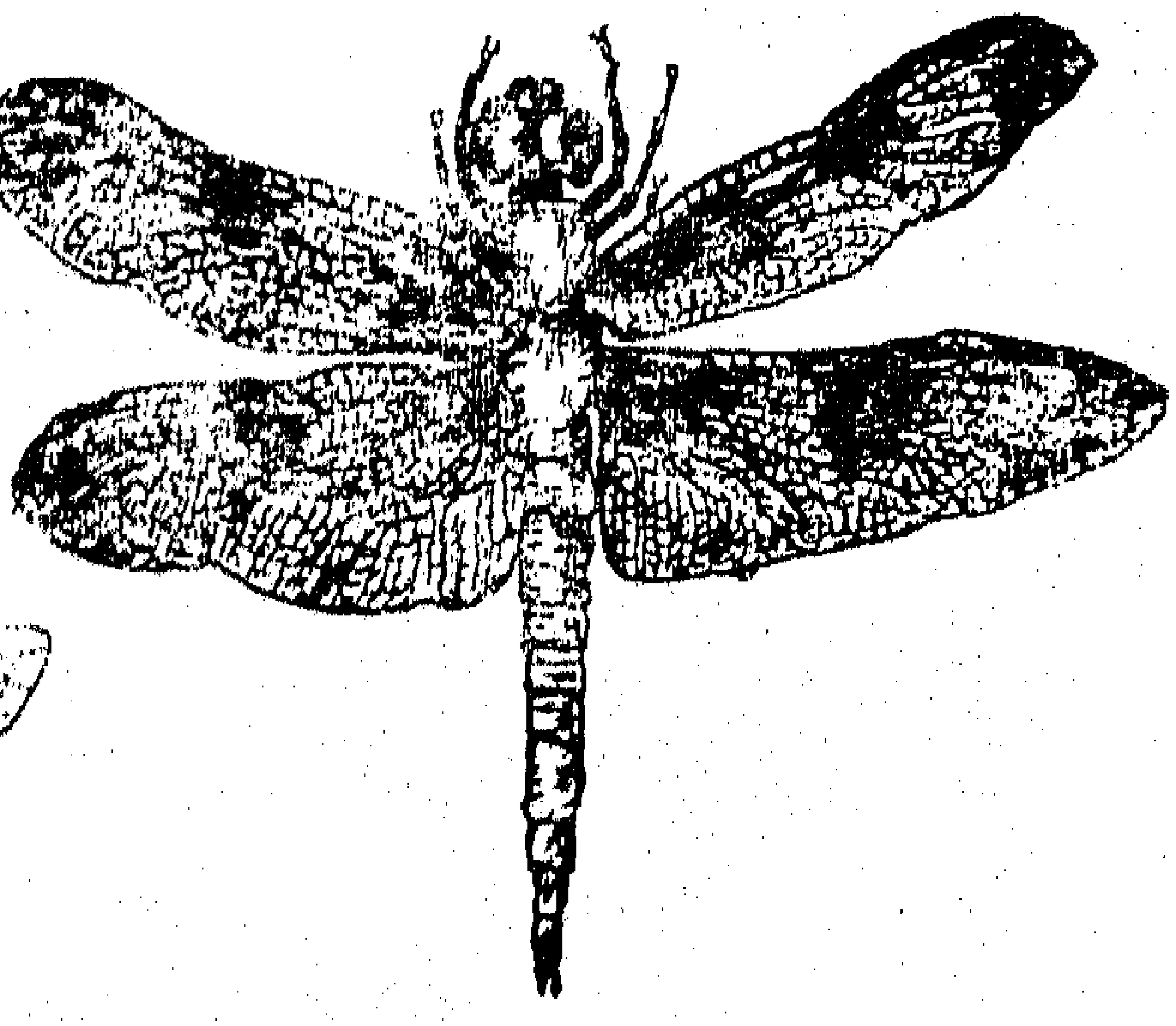

Fig. 38. *Dragonfly*

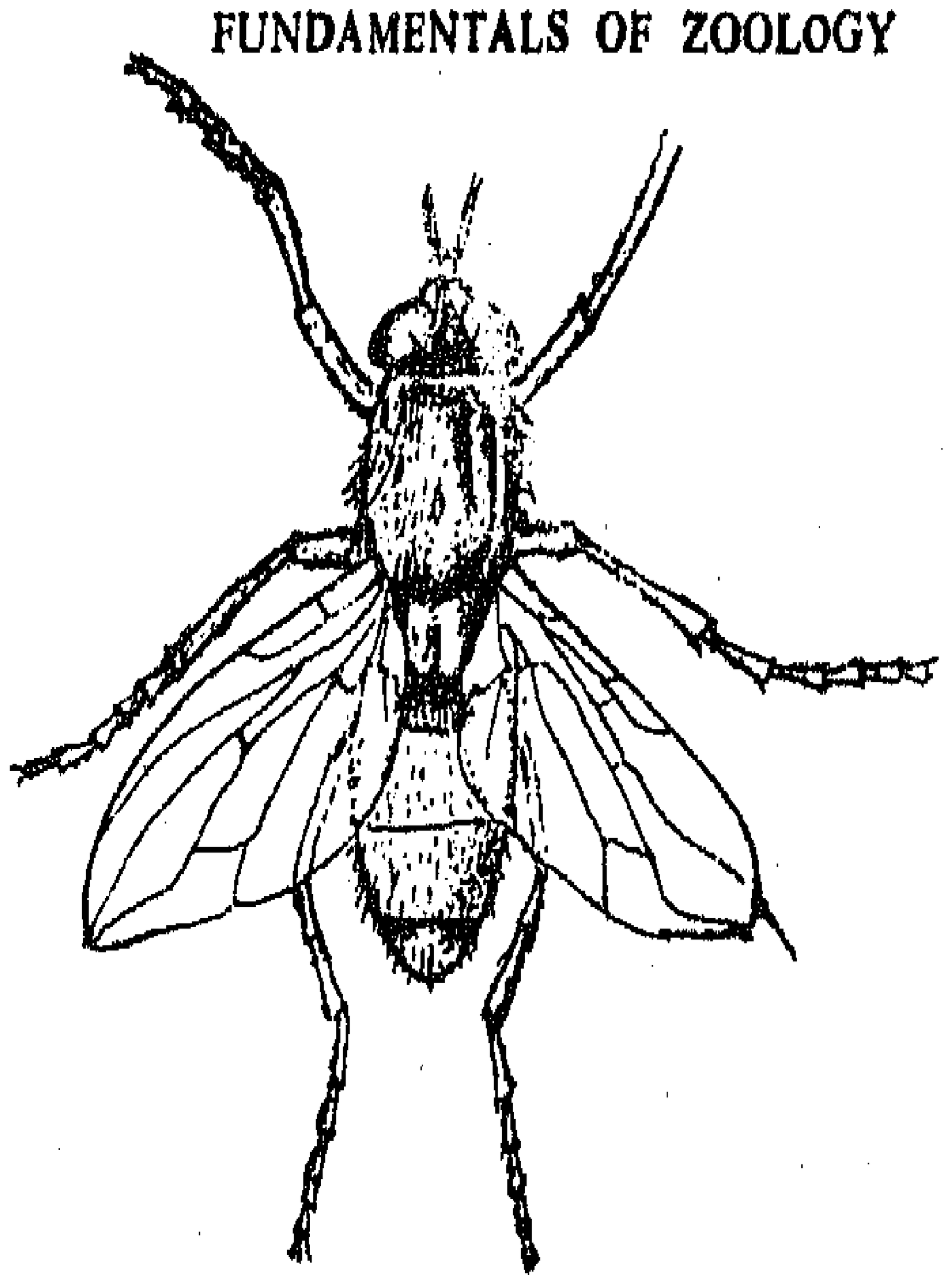

Fig. 39. *Housefly*.

three pairs of walking legs and two pairs of wings. The abdomen has eleven or fewer segments. Respiration is by means of branched tracheae, lined with cuticle. Excretion is by malpighian tubules attached to the anterior end of the hind-gut ; *e.g.*, Cockroach (Fig. 35), Honey bee (Fig. 36), Butter fly (Fig. 37), Dragon fly (Fig. 38), House fly, (Fig. 39), Mosquito, Stick insect (Fig. 40), Siver fish, Bed bug, Beetle, Grasshopper (Fig. 41), Ants, and Crickets.

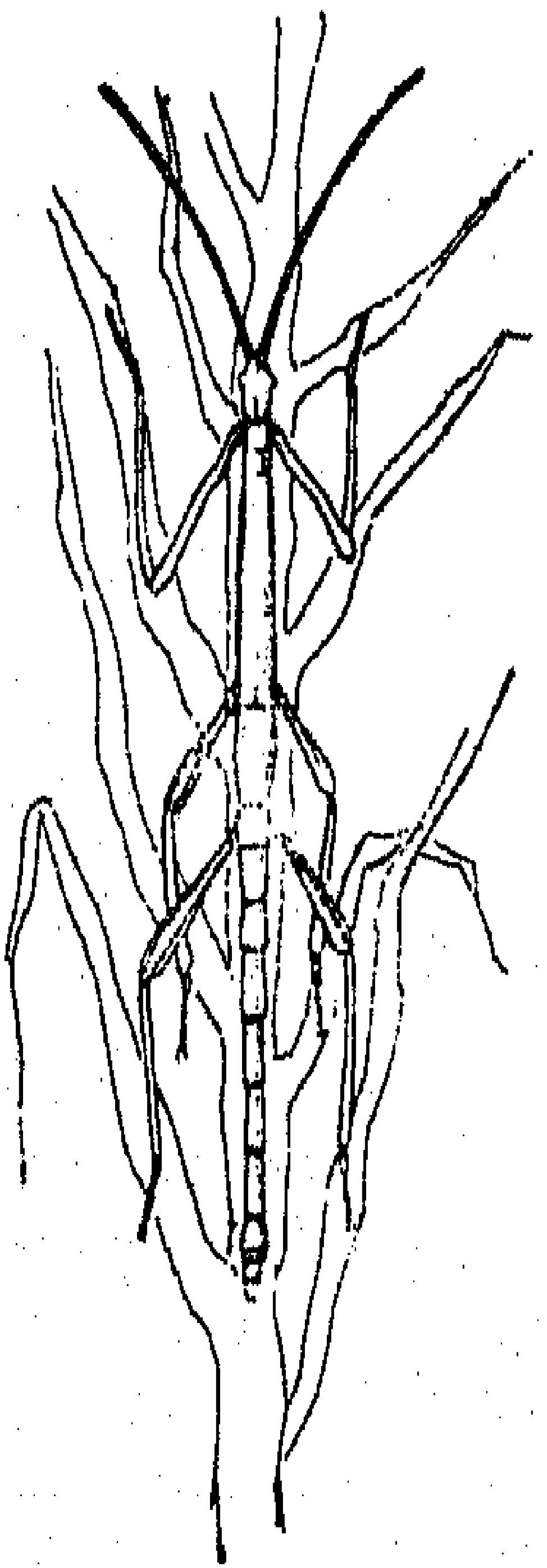

Fig. 40. *Stick insect*

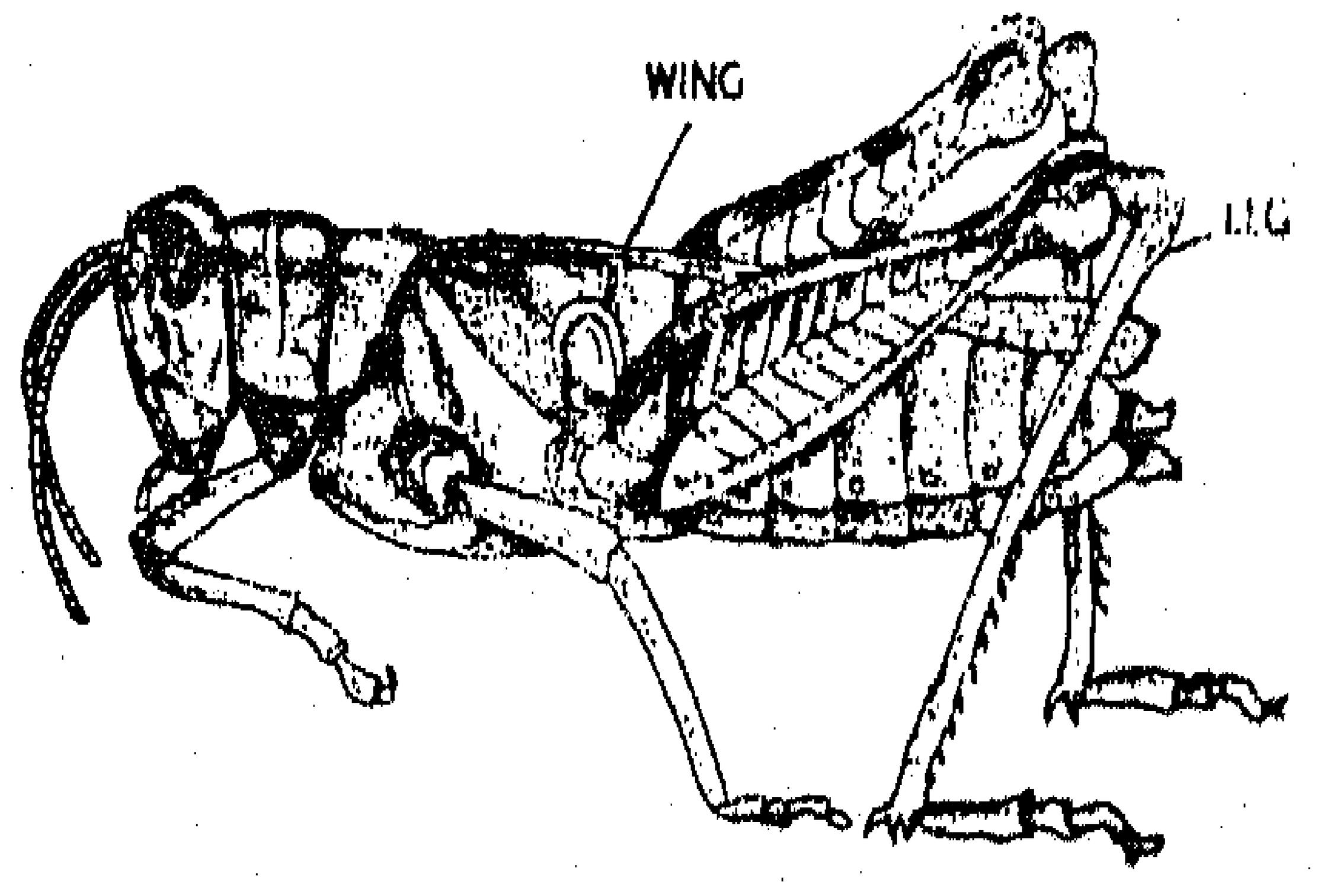

Fig. 41. *Grasshopper*

Cockroach. Cockroaches are found in kitchens and store-houses as well as in drainage pipes. They are not only a nuisance to mankind but are also the carriers of certain diseases. They are nocturnal in habit (*i.e.*, they come out normally during night time in search of food). The body is divisible into head, thorax and abdomen. The head bears a pair of antennae and a pair of kidney-shaped compound eyes. The mouth has a pair of cutting jaws or mandibles. The thorax is of three segments, each segment having a pair of jointed walking legs. There are two pairs of wings, the second pair of wings is thin and membranous and is used in flight, while the first pair serves as wing covers for the second pair of wings. The abdomen is made up of ten segments. The entire body is covered by a chitinous exoskeleton.

Butter fly. The body, as in any other insects, is divisible into head, thorax and abdomen. The thorax has three pairs of walking legs and two pairs of functional wings, which are beautifully coloured. The mouth part is in the form of a long coiled tube —the proboscis—and is used for sucking nectar from the flowers.

House fly. They are of great importance to man because they spread the germs of dreadful diseases like typhoid, cholera, and dysentery. They breed in decomposing organic matter. They have powerful sponging mouth parts in the form of a proboscis.

Class-Arachnida

The arachnids are arthropods which include spiders, scorpions. king-crabs, ticks and mites. They are mostly terrestrial, with two pairs of mouth parts—*e.g.*, chelicerae and pedipalpi—and with four pairs of legs. They have no true jaws, nor antennae. The body is divided into the cephalothorax and abdomen. The eyes are simple. Tracheae, or book-lungs (organs having sheets or lamellae in the form of books), are the organs of respiration.

Scorpions. They live in crevices or in pits the sand or stones during day time, and actively run about at night, in search of food. (Fig. 42) They catch insects and spiders with their pedipalpi and tear them apart with their chelicirae, normally after paralyzing them by the sting which has a poison gland, present at the end of the tail.

The body is divisible into cephalothorax (prosoma) and an abdomen of two parts—an anterior thick portion (mesosoma) and a slender tail (metasoma), which is always held over the back when the animal moves. The sting, with its poison gland, is attached to the last segment of the post-abdomen or metasoma. The sting has curved spine for piercing. The cephalothorax has a pair of median eyes on the dorsal side and three lateral eyes on each side. The scorpion has four pairs of walking legs; while a pair of chelicirae and a pair of pedipalpi are present at the anterior side. Four pairs of book-lungs open by means of stigmata on the under surface of the abdominal segments. Scorpions are unisexual and viviparous (*i.e.*, they give birth to live young ones).

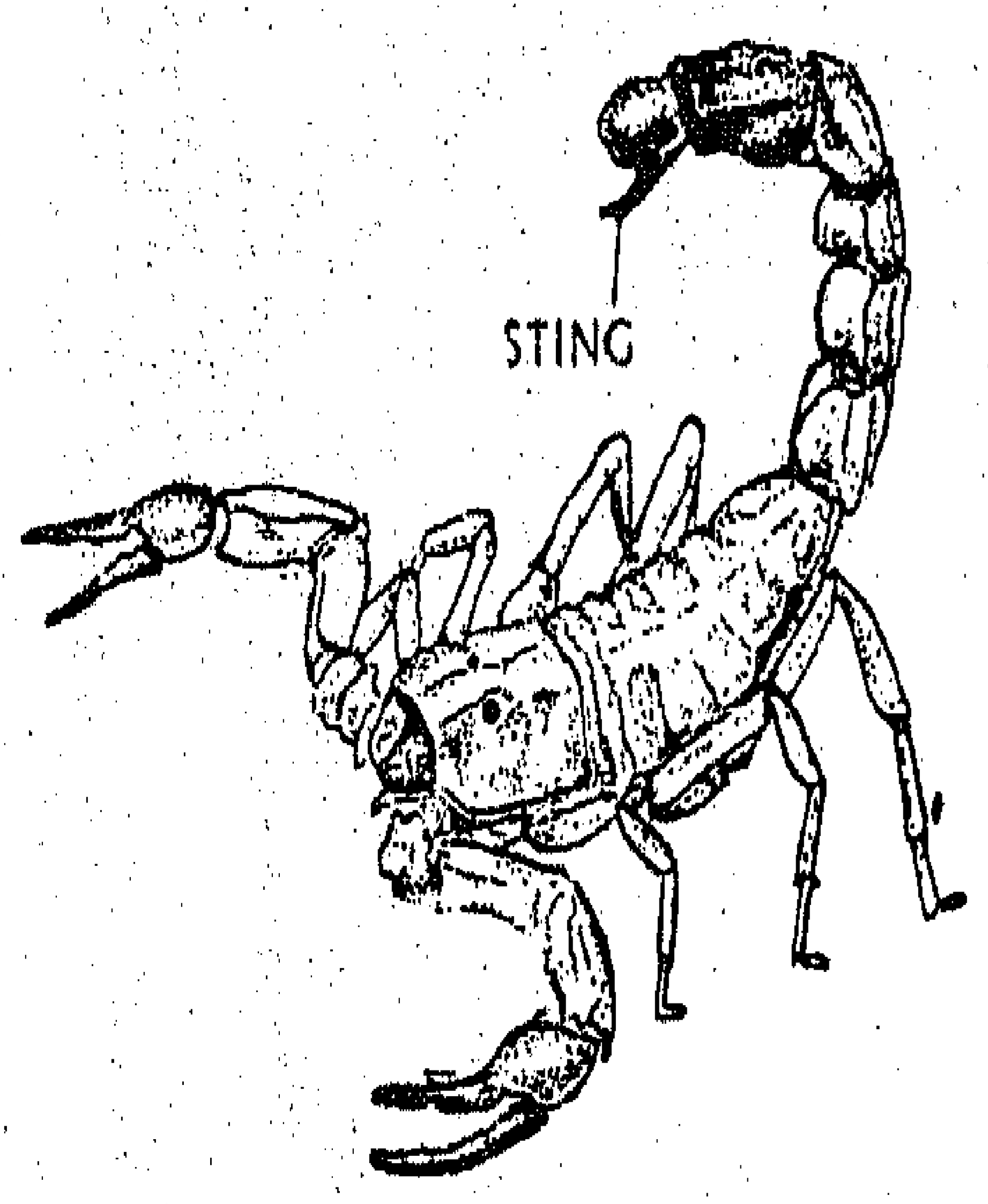

Fig. 42. *Scorpion*

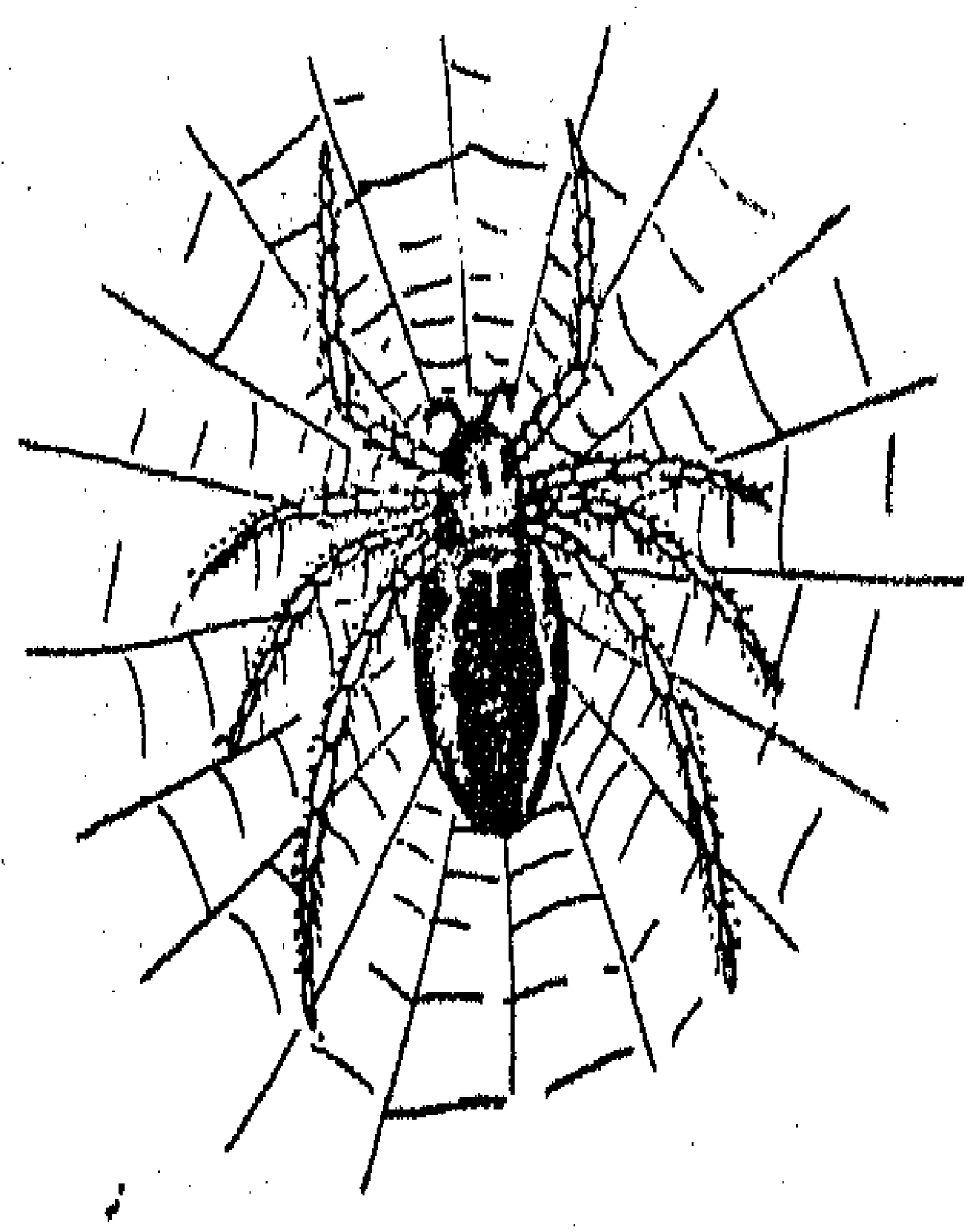

Fig. 43. *Spider*

Spider. (Fig. 43) The body has a distinct cephalothorax and an abdomen. Both the parts are rounded and unsegmented. The cephalothorax bears 4 pairs of legs, a pair of chelicirae (with a pair of poison glands in each) and a pair of pedipalpi. They have spinning glands for weaving web. The sexes are separate. Eggs are laid in a silk cocoon, which is attached to the web or to a plant or carried about by the female.

Class-Myriapoda

The centipedes and the millipedes are included in this class. They are elongated, worm-like animals with a distinct head and a uniformly segmented trunk. The head bears groups of simple eyes, a pair of jointed antennae and two or three pairs of jaws. Each segment of the trunk region bears one or two pairs of jointed legs, which are similar throughout. Respiration is by tracheae.

Centipede. (Fig. 44) The body is enlongated, segmented and flattened. The head bears a pair of antennae and groups of simple eyes. The mouth has a pair of biting jaws. The rest of the body is divided into a number of somites. The first somite bears a pair of poison claws, while each of the other somites bears a pair of jointed walking legs. They live under stones or logs, and come out at night in search of prey which is killed by the poison poured out from a duct in the claw.

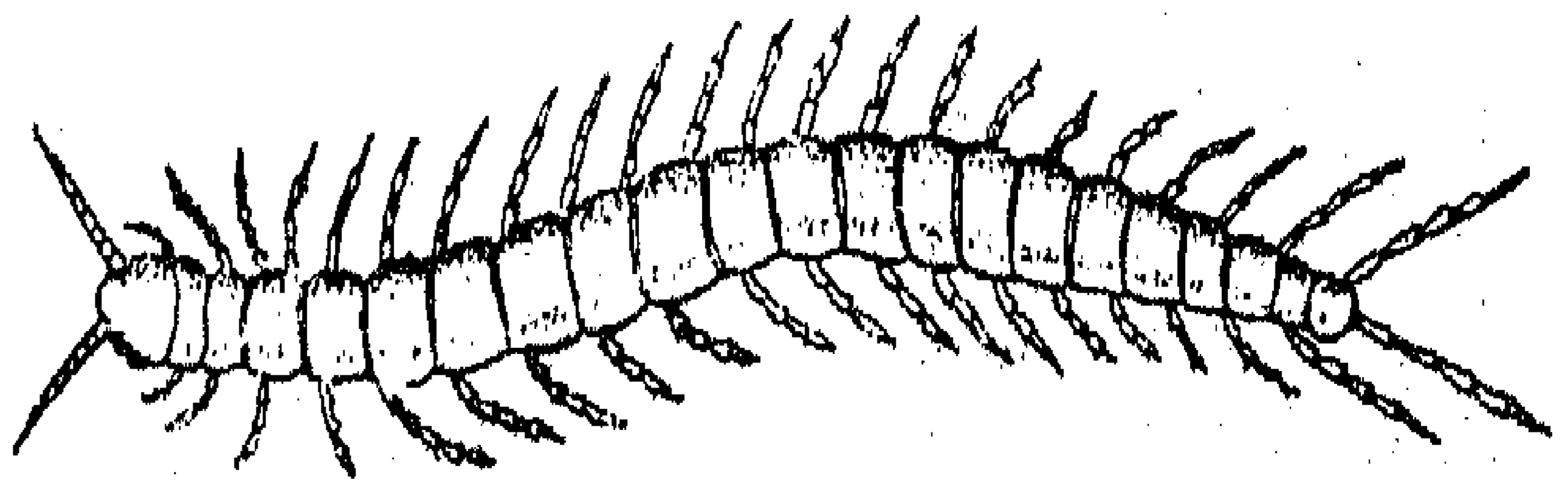

Fig. 44. *Centipede*

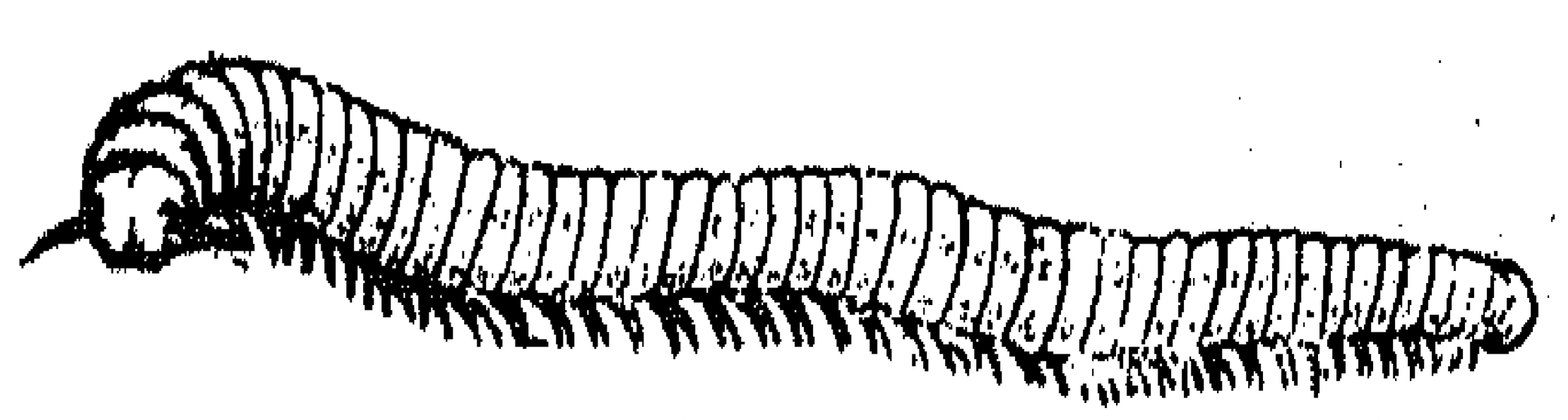

Fig. 45. *Millipede*

Millipede. (Fig. 45). The millipedes have cylindrical bodies of many segments. The head bears a pair of short antennae and a pair of groups of many simple eyes. The mouth parts include a pair of biting jaws. The region after the head, which is of about 4 somites, is the thorax ; and each somite bears only one pair of legs. The rest of the body is the abdomen, whose segments bear two pairs of legs each. They live in dark places, beneath stones or within rotting wood, and avoid light. They move slowly and eat dead plant material as well as animal matter. Some species roll up in a spiral when disturbed.

Phylum-Mollusca

They are unsegmented, triploblastic and bilaterally symmetrical animals. They usually possess a shell of calcium carbonate. Animals belonging to this phylum have a soft unsegmented body, which is divisible into head, foot and visceral mass. The foot is ventral and muscular, and is generally used either for creeping over surfaces or for ploughing through mud. It usually serves for locomotion, but is much modified according to habits.

The body is typically enclosed in a dorsal or lateral fold of the body wall, which forms a mantle or *pallium* and which often secretes a calcareous shell of single or double pieces which, in some, number as many as eight. The shell may be either internal or external, or, in certain others, entirely lacking.

The mantle encloses a space, the mantle cavity, within which lie the gills and the other organs. The digestive tract is complete. The mouth has a chitinous ribbon or *radula* bearing chitinous teeth, and the anus opens into the mantle cavity. The salivary glands are often present, and a digestive gland (hepato-pancreas) opens into the stomach. The coelom is reduced and restricted to the cavities of the pericardium, the kidneys and the gonads.

The circulatory system is almost always well developed with a dorsal heart.

The respiratory organs are the gills or ctenidia, or the respiration is by the mantle. Excretion is by kidneys. The nervous system consists of 3 pairs of ganglia : (i) The cerebral pair of ganglia in the head region above the mouth ; (ii) The pedal pair in the foot ; and (iii) The visceral or pleural in the body region. These are joined by longitudinal and transverse connecting nerves. The sexes are usually separate (unisexual) ; in some they are united (hermaphrodite) *i.e.*, bisexual.

The animals belonging to this phylum are mostly marine, though some live in fresh water and brackish water, and some are terrestrial ; *e.g.*, Chiton, Land snail, Slug, Pila, Bivalve, Sepia, Octopus.

Chiton. (Fig. 46). It is marine, and is found attached to the surface of rocks. The body is elongated, dorso-ventrally flattened. The dorsal surface is covered by eight calcareous plates. The head is not well developed, and lacks both tentacles and eyes.

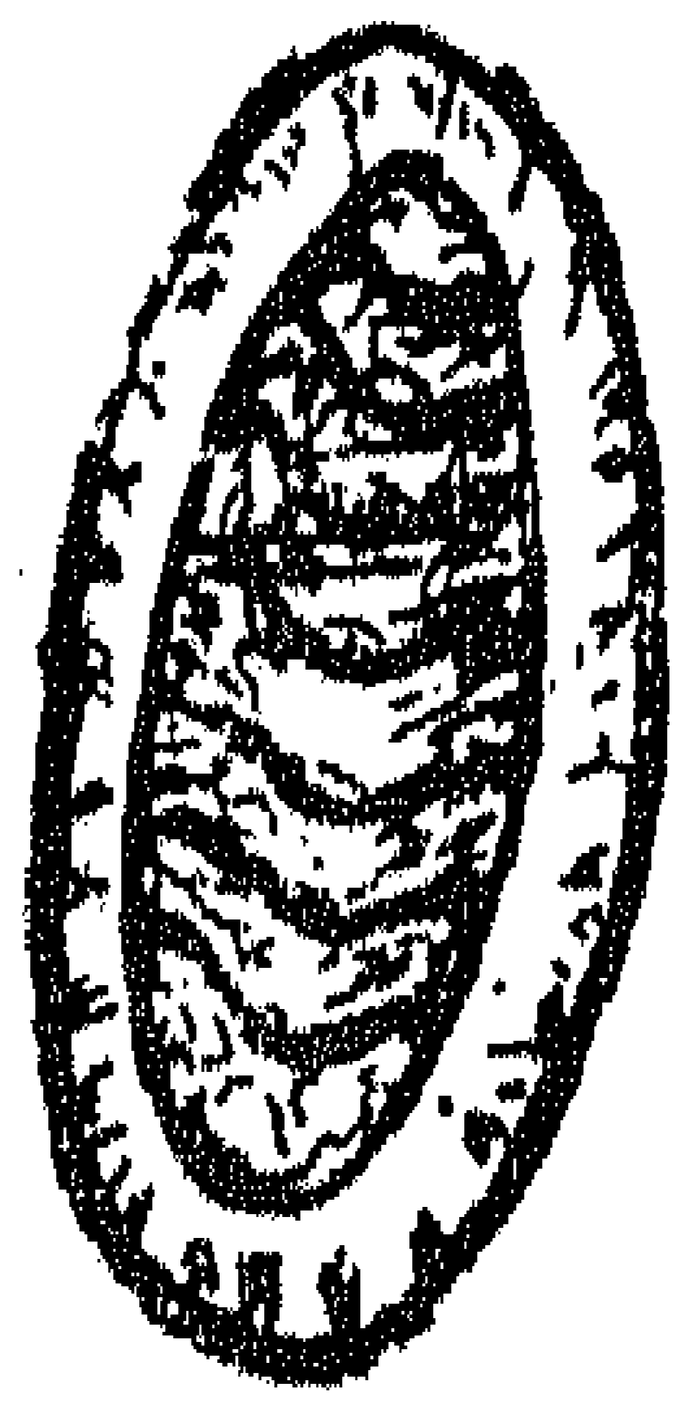

Fig. 46. *Chiton*

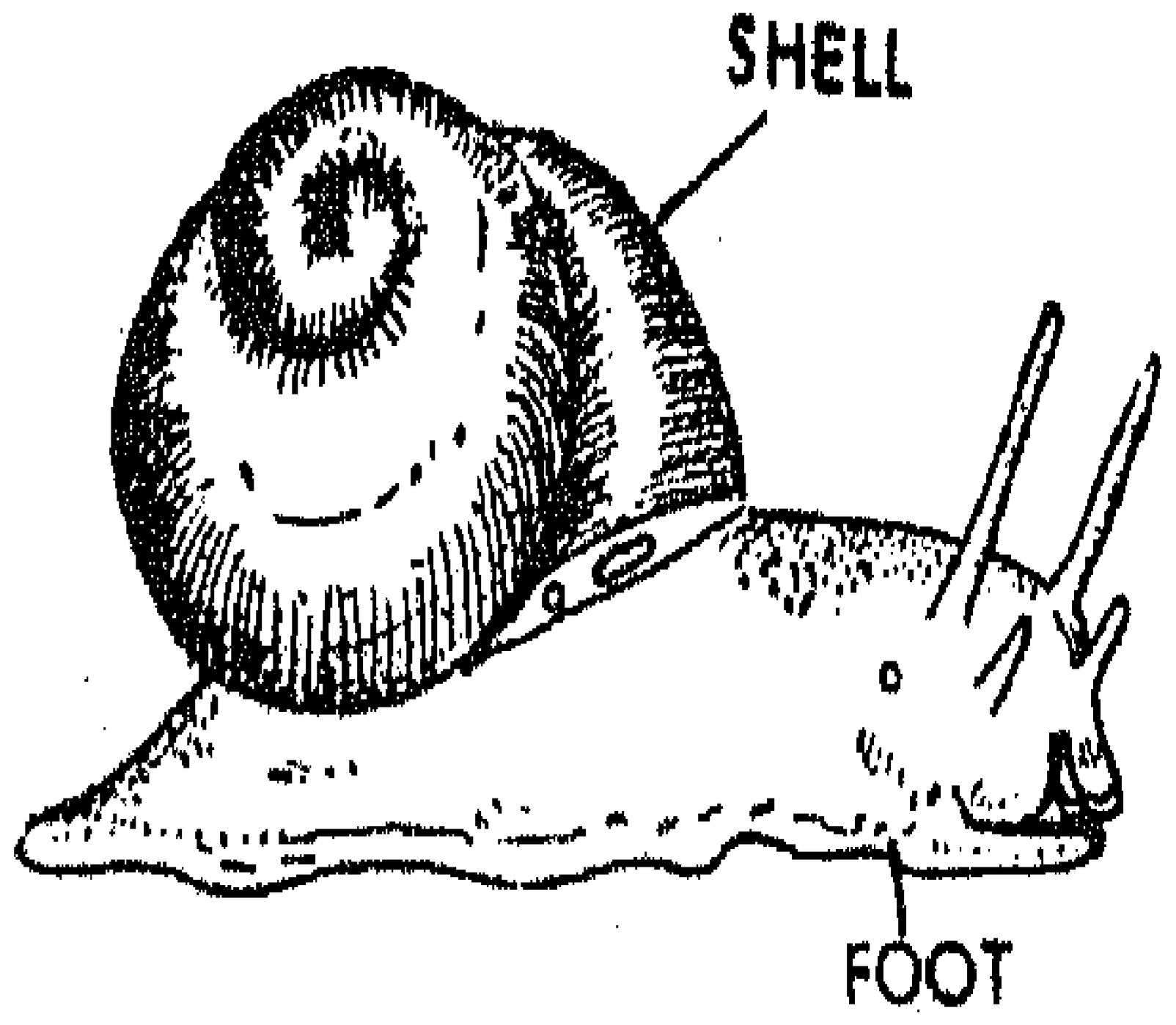

Fig. 47. *Snail*

Snail (Ariophanta). (Fig. 47). The body of a snail consists of a head bearing two pairs of tentacles, a pair of eyes on tentacles, and a mouth. A large muscular foot, by which the animal creeps, has mucuous secreting glands. Over the foot is a spirally coiled shell of one piece, made up of calcium carbonate. It encloses the visceral mass. Part of the mantle is modified into a lung with a net-work of blood capillaries, and forms the respiratory organ. The sexes are united.

The *slug* is similar in all respects with the snail, but is without a shell.

Pila (Apple snail). (Fig. 48) It is usually found in fresh-water ponds, lakes and paddy fields. The body is enclosed in a spirally coiled shell. The mouth of the shell can be closed or opened by a

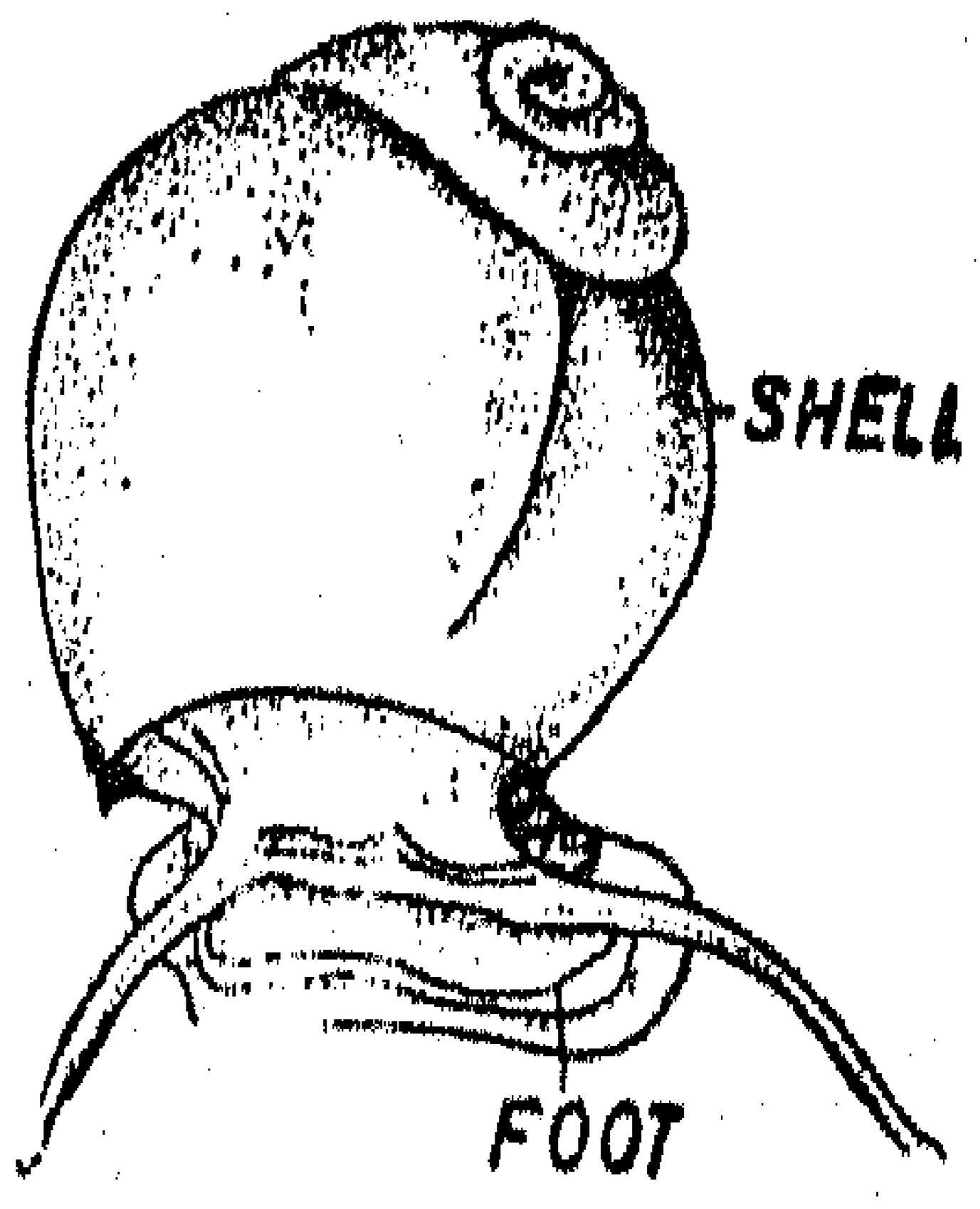

Fig. 48. *Pila*

flat lid-like plate, the operculum. The body has a head, a foot and a visceral mass. The head is provided with eyes and tentacles. The foot is flat on which the animal creeps.

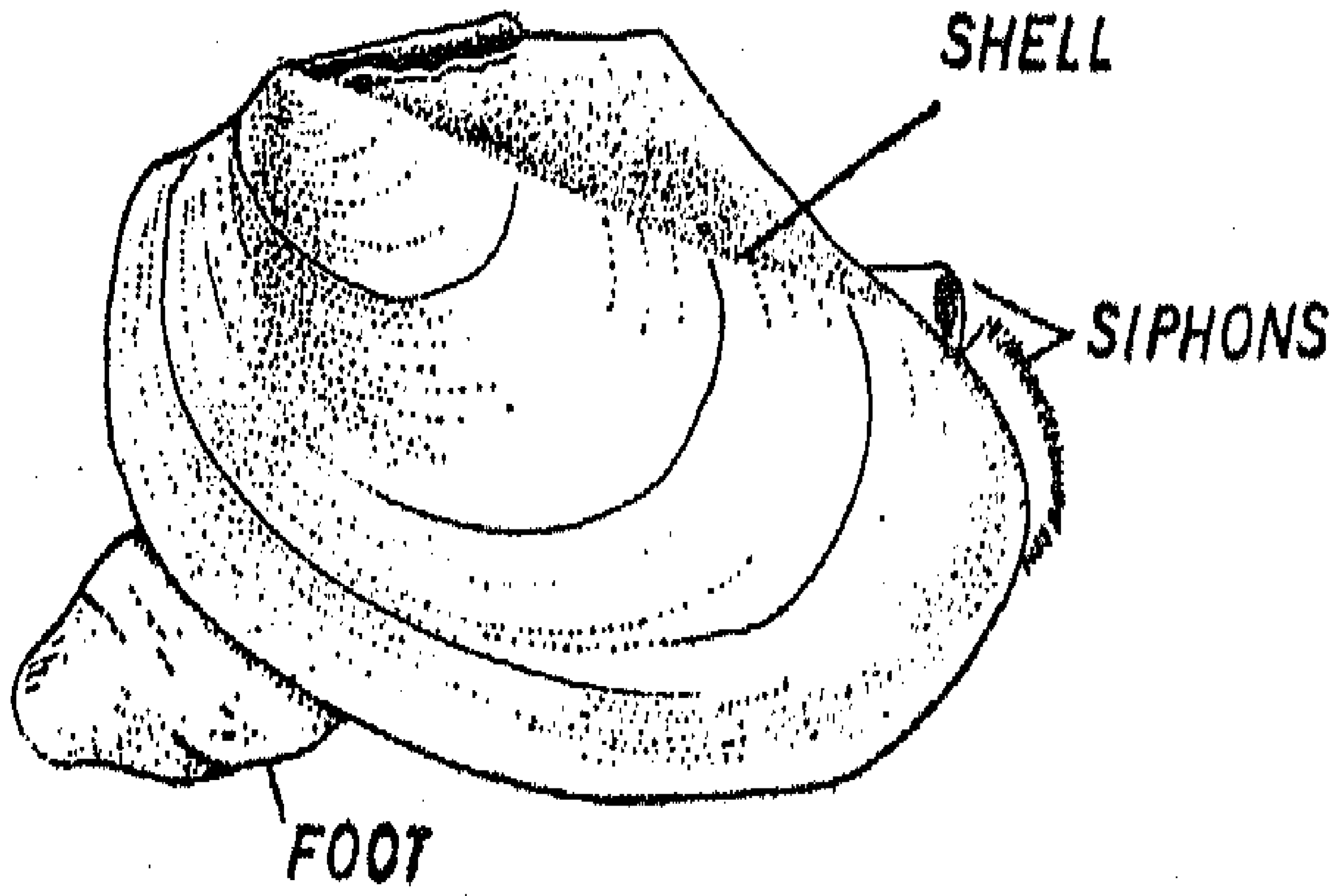

Fig. 49. *Unio*

Unio (Bivalve, *i.e.*, fresh-water mussel) : (Fig. 49)—They are bilaterally symmetrical with a body compressed from side to side. (Fig. 49) The mussels usually lie almost buried in the muddy or sandy bottoms of takes or streams. They burrow and move from place to place by means of a keel-shaped or wedge-shaped foot, which can be protruded out from the anterior end of the shell. At the other end, there is a ventral or inhalant siphon and a dorsal or exhalant siphon through which the water is thrown out.

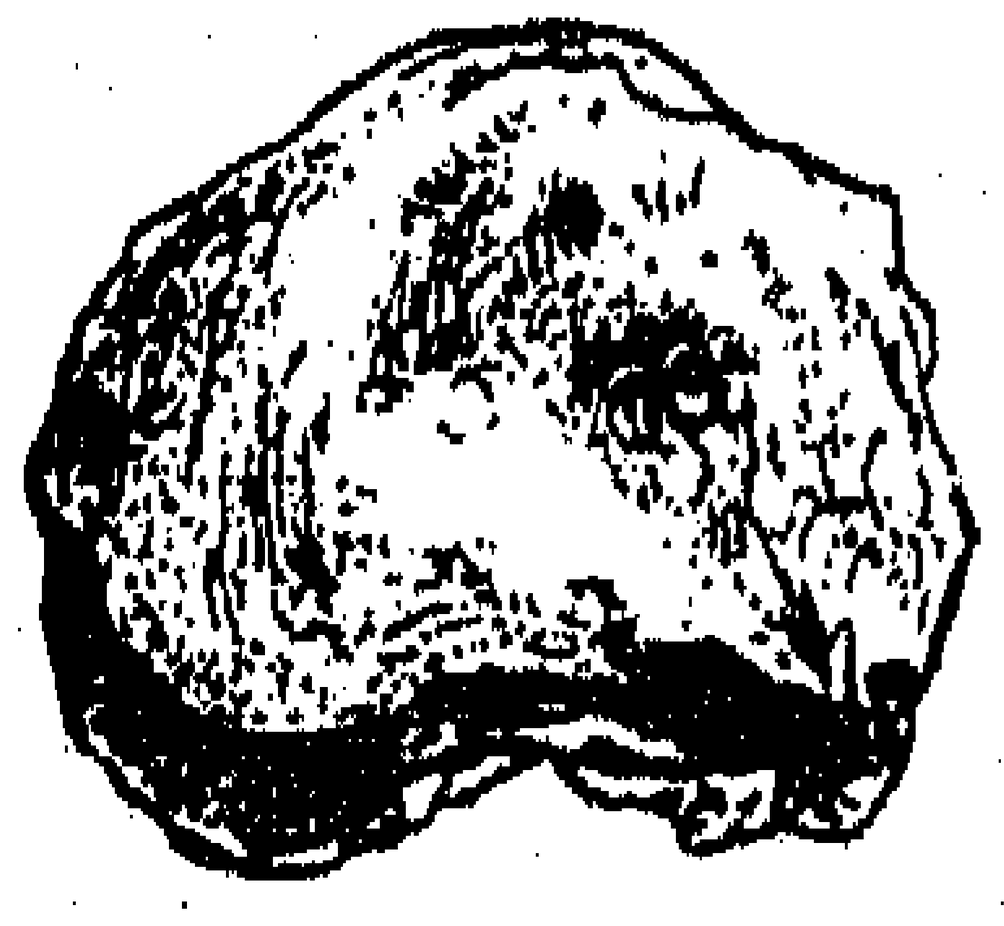

Fig. 50. *Oyster*

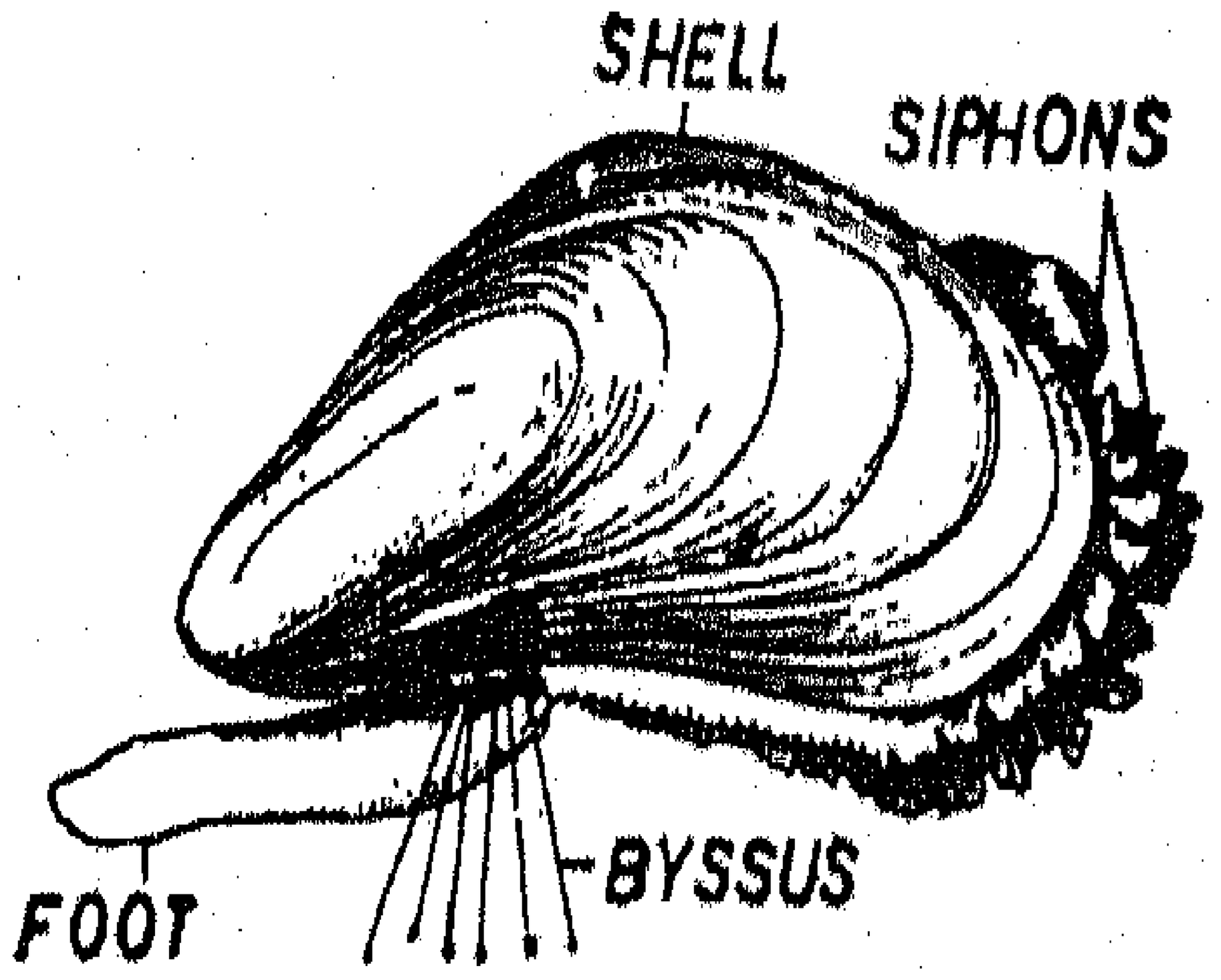

Fig. 51. *Mytilus*

The head is undeveloped, without eyes or tentacles. The body is enclosed in a shell of two valves or parts, which are joined on the dorsal side by an elastic hinge ligament. The shell valves are marked externally with concentric lines of growth.

The other examples of bivalves are pearl oyster, oyster, Ostrea (Fig. 50), Mytilus (Fig. 51) and Teredo (Shipworm).

Sepia (Cuttle fish) (Flg. 52). It is marine and bilaterally symmetrical. The head bears two large eyes and a central mouth, which is surrounded by ten fleshy arms having cup-like suckers. One pair of arms is long and is called as tentacles. Their club-shaped free ends are provided with suckers. These arms are a modified part of the foot. The mouth has a pair of jaws which are beak-shaped. The head and the body are joined by a neck, on the ventral side of which is a muscular funnel or *siphon*. The siphon is the remaining part of the foot modified. The body is conical and is covered over by a thick integument, the mantle. The tapering end of the body on either side has a thin muscular fold, the fin, which is used

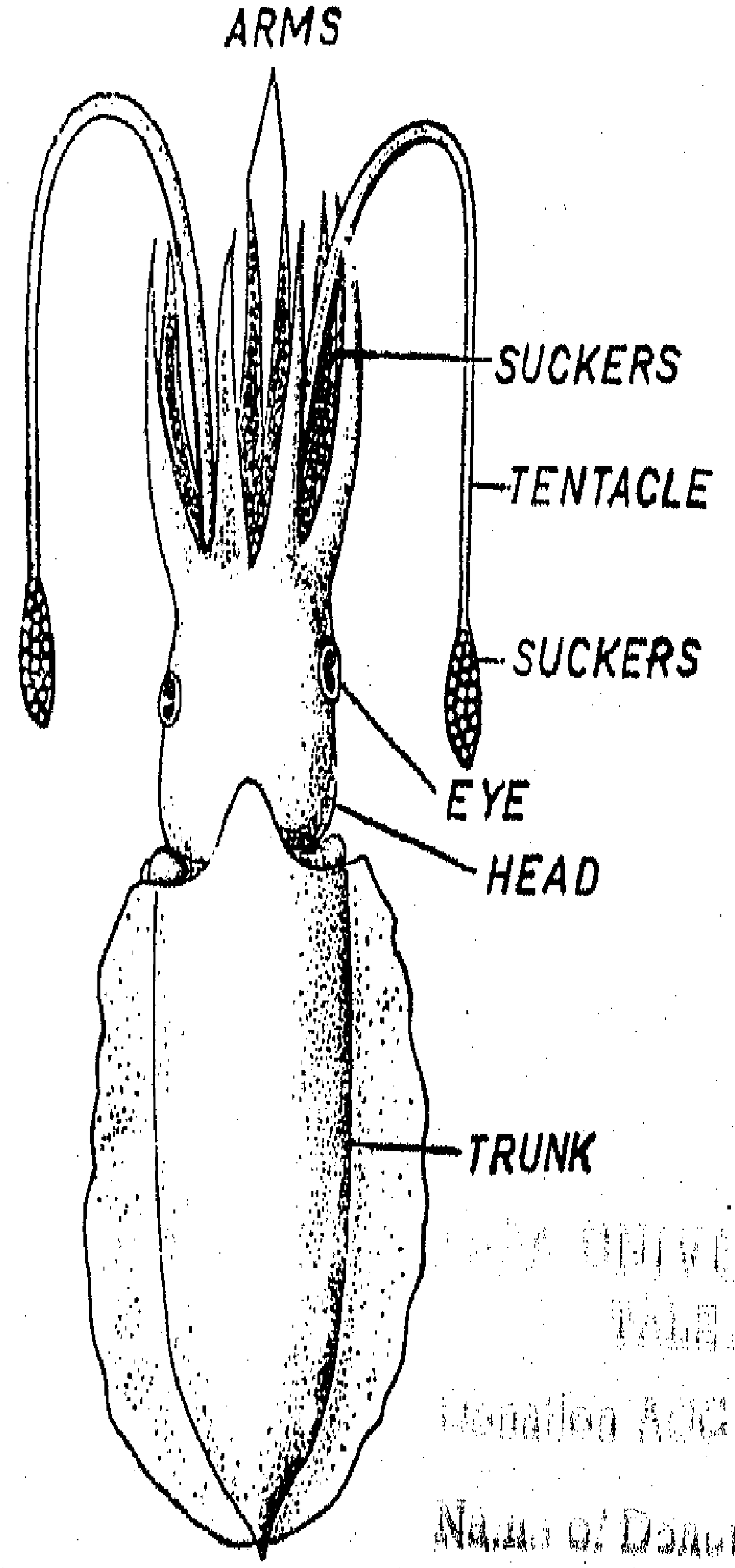

Fig. 52. *Sepia*

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for swimming. The shell is internal and embedded in the mantle wall on the dorsal side. The rectum opens at the base of the siphon along with the duct of an ink-sac. The dark ink, the sepia, is thrown out through the siphon when the animal is disturbed, making the water turbid and cloudy. Under cover of this *smoke screen*, it escapes from the enemy.

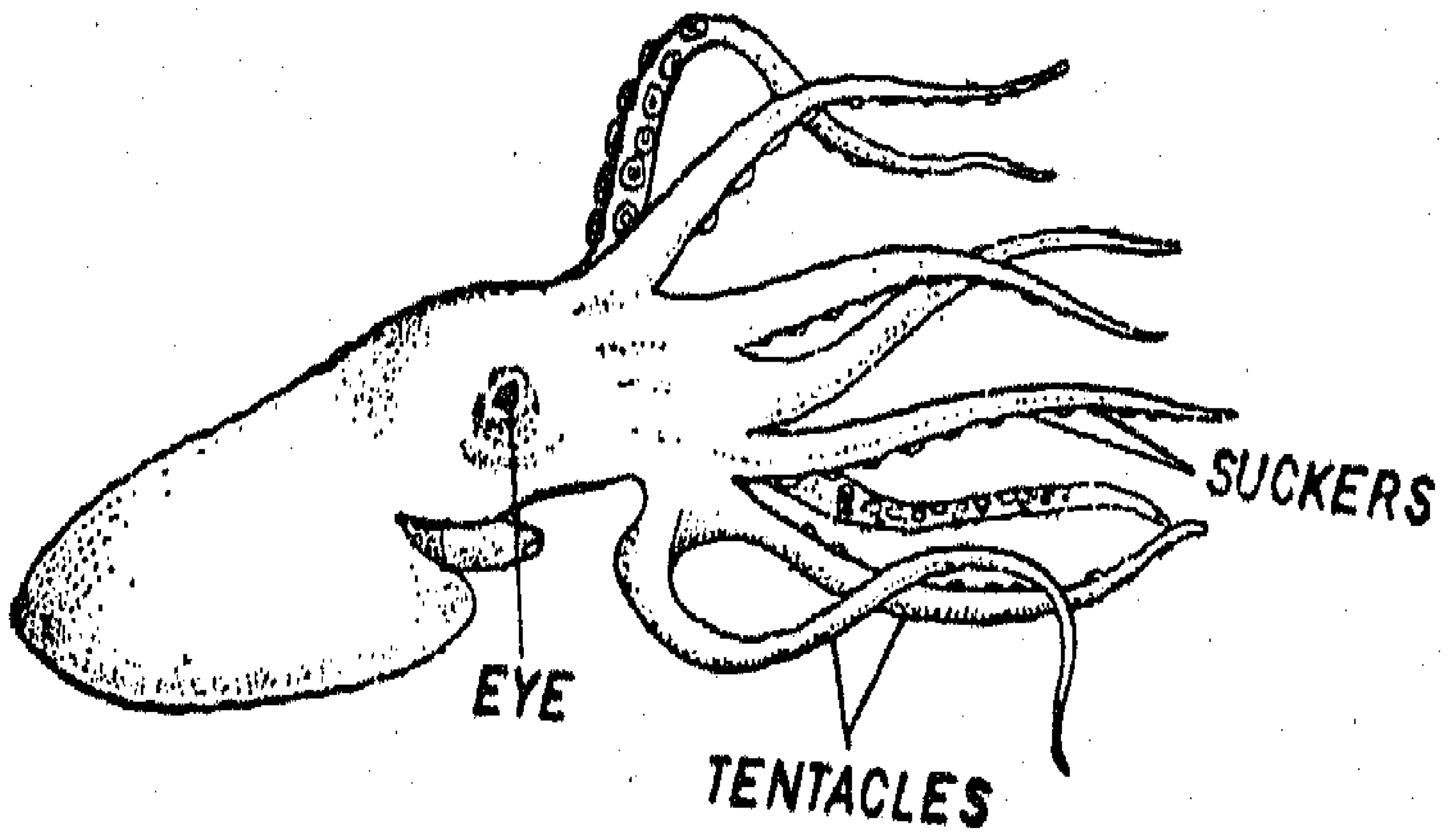


Fig. 53. *Octopus*

Octopus. (Fig. 53). It is also a marine animal. A large octopus is dangerous even to human beings. It has almost a globular body with a distinct head, which bears a pair of eyes, and only 8 tentacles provided with cup-like suckers as in the sepia. The shell is absent.

Phylum-Echinodermata

All the members belonging to this phylum are exclusively marine. They have a body which is radially symmetrical, triploblastic and coelomate. They usually have a body of 5 parts in the adult (pentamerous), bur no head nor segmentation. Most of them have an endoskeleton of plates of calcium carbonate, embedded in the body wall, with protruding spines. (The name of the phylum itself is suggestive of the presence of a spiny skin.) Locomotion is by means of tube feet, which are connected to a characteristic system of water-filled vessels radiating from a circular canal surrounding the mouth. This system is known as the "water vascular system".

The digestive tract is simple, and usually complete. The circulatory system is radiate, but is reduced. Respiration is by minute gills or "papullae" protruding from the coelom, by tube feet, and in some (holothurians) by the "cloacal respiratory tree".

The nervous system has a circular oral nerve ring and radial nerves. The sexes are usually separate, alike externally. A few reproduce asexually by self-division, and many regenerate lost parts; e.g., Starfish, Brittle star, Sea-urchin, Sea-cucumber.

Starfish. (Fig. 54) The body consists of a central disc and five radiating arms or rays. It is covered by a tough skin, which is provided with spicules or plates of calcium carbonate, forming an endoskeleton. The mouth is ventral, and radiating from this into each arm is a groove—the *ambulacral groove*—in which are seen projecting out in two rows of delicate tube feet, which are the organs of locomotion. These tube feet are connected to an underlying radial canal of the water-vascular system. This system opens on the dorsal surface by an opening, the *madreporite*, through which water enters into this system. The anus lies on the upper surface. On the tip of each arm is a tentacle and a light sensitive eye-spot.

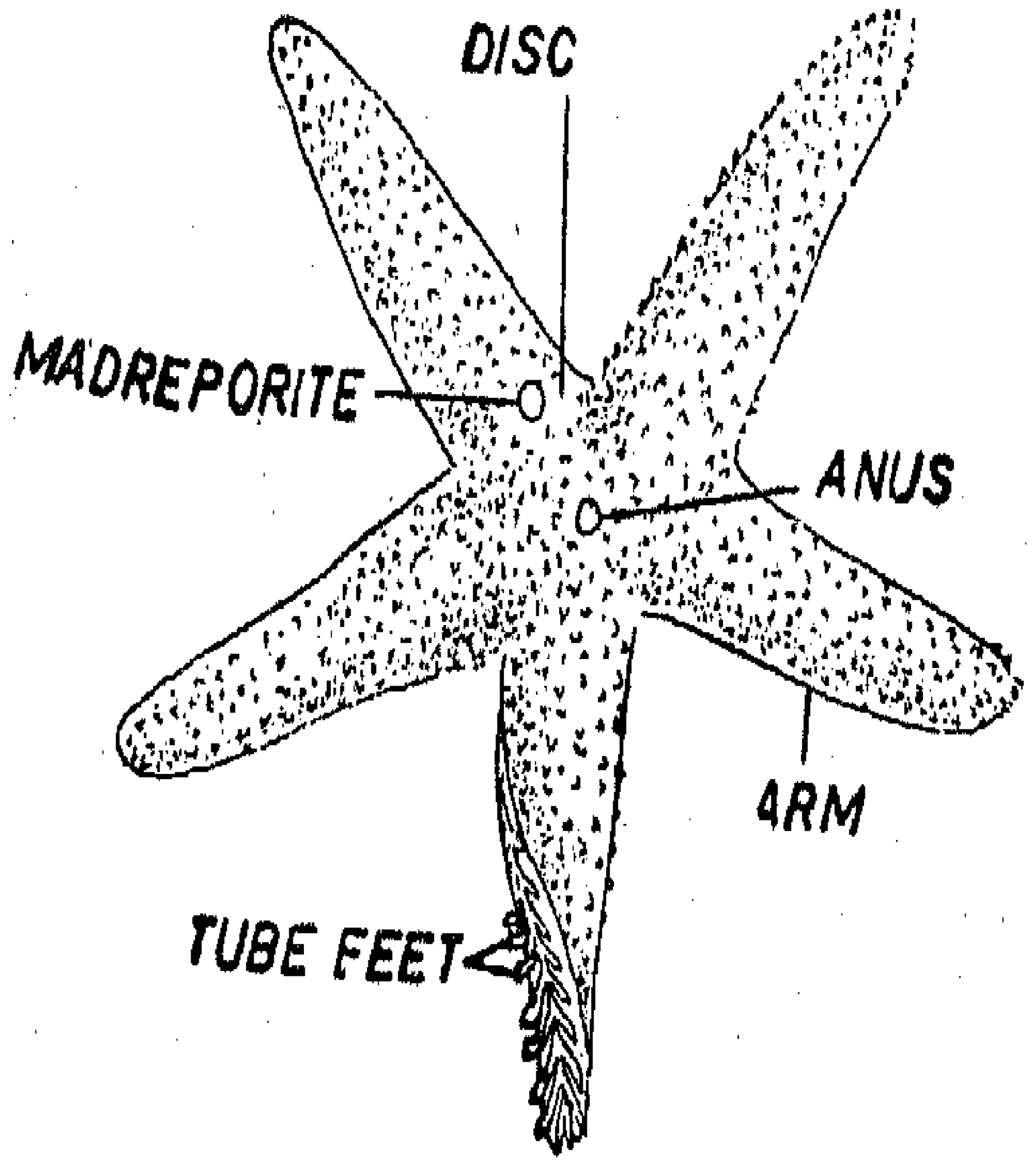


Fig. 54. *Starfish*

Brittle star. (Fig. 55) The central disc is distinctly marked off from the five radiating arms, which are slender. (Fig. 55) These are without the ambulacral grooves. The mouth and madreporite are on the oral surface. There is no anus. Small tube feet project on either side of the arms. Arms are very brittle and break off easily, and thus justify its name. The lost arm is regenerated.

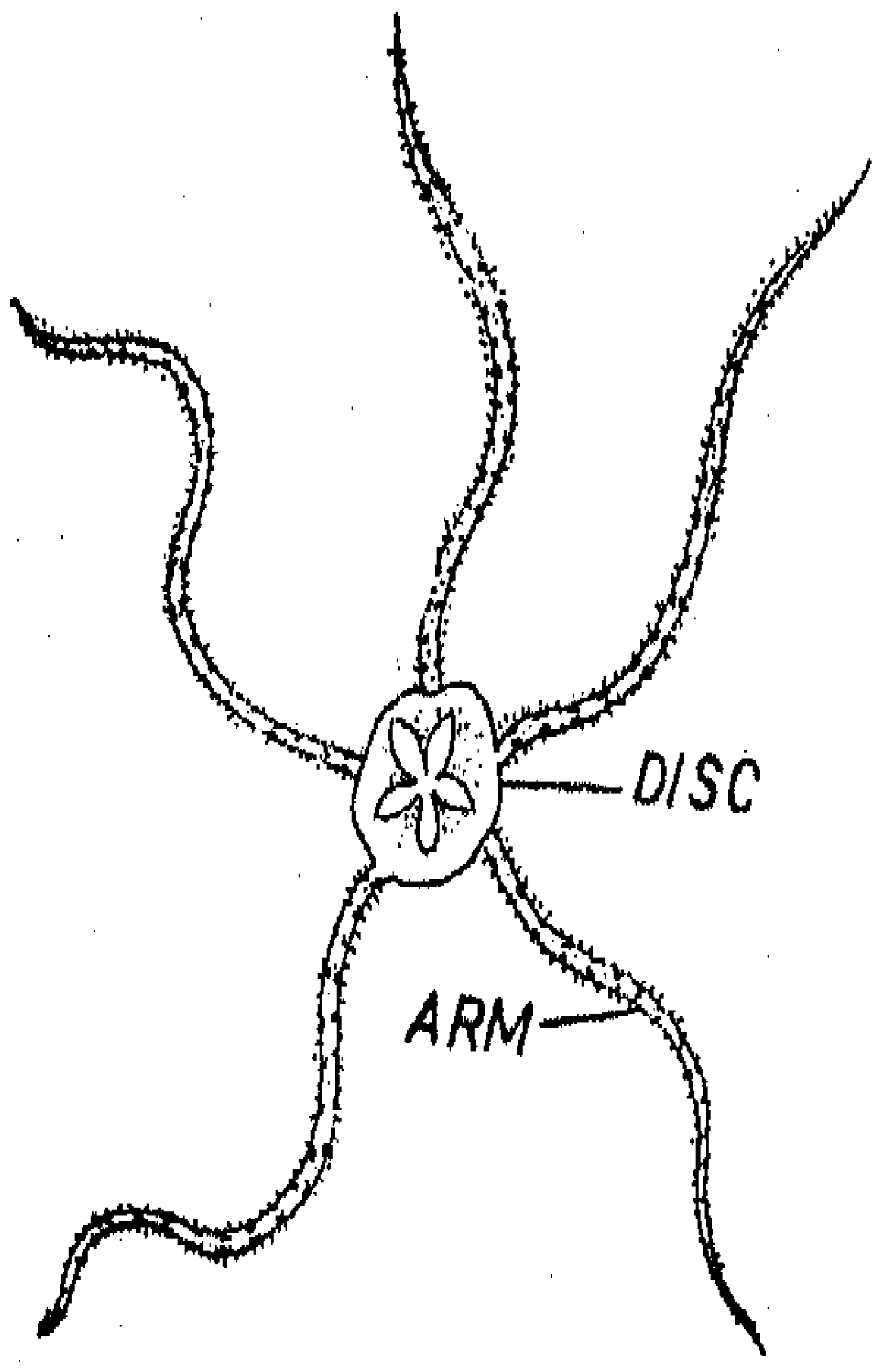


Fig. 55. *Brittle Star*

Sea urchin. (Fig. 56) It has a rounded body and has no arms. The body is enclosed in a test or shell made up of calcareous plates which are firmly joined together and are arranged in 10 double rows. The shell bears long sharp movable spines. From five areas come out a double series of long slender tube feet. These areas represent the arms of the starfish. The mouth is on the oral surface and is surrounded by five strong sharp teeth, which are supported by a complex framework inside the shell, known as Aristotle's *lantern.* The anus is on the aboral surface.

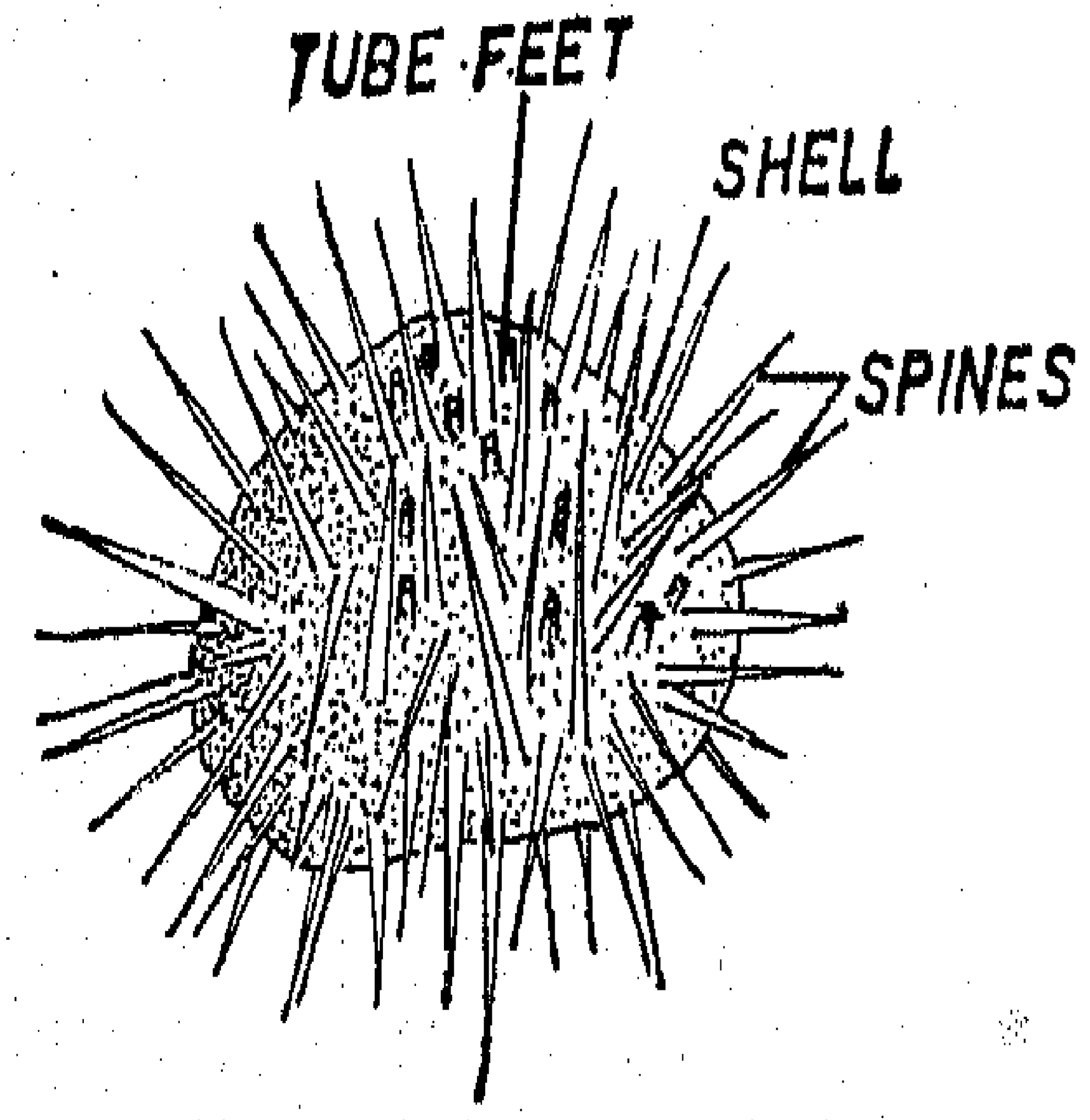


Fig. 56. *Sea Urchin*

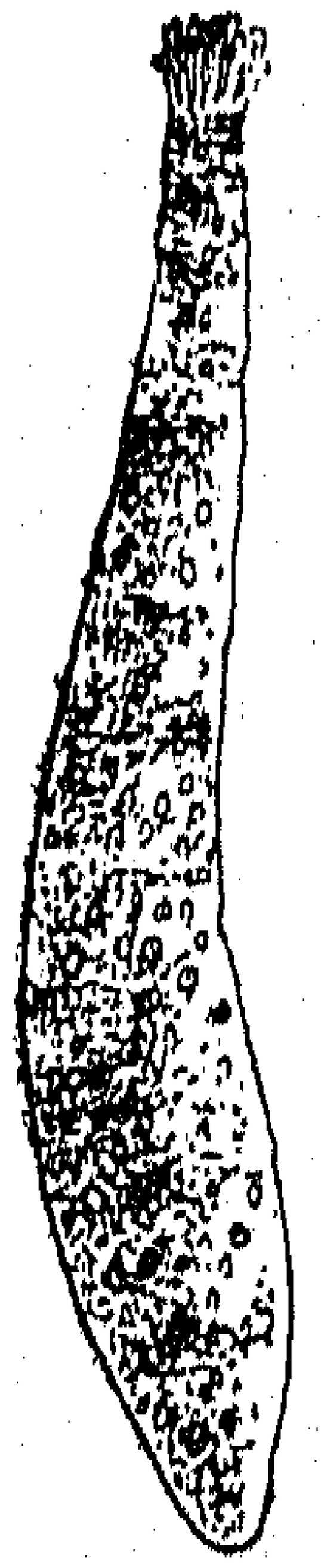


Fig. 57. *Sea Cucumber*

Holothurian (Fig. 57) (Sea cucumber). The body is cylindrical, muscular and without spines. The skin is leathery, containing microscopic calcareous plates. The mouth is situated at one end of the body and is surrounded by tentacles. The anus is posterior. Tube feet are distributed over five radii.

SUB-PHYLUM—VERTEBRATA

The sub-phylum vertebrata is divided into five classes, namely, (i) Pisces (Fishes); (ii) Amphibia; (iii) Reptilia (Reptiles): (iv) Aves (Birds); and (v) Mammalia (Mammals).

Class-Pisces

Fishes are cold-blooded (Piokilothermal—where the body temperature cannot be maintained at a particular norm, but changes with the surrounding atmospheric changes), aquatic vertebrates with fins as locomotor organs and gills as respiratory organs. The nasal cavity normally has no internal nostrils. The heart is two-chambered, with one thin-walled auricle (atrium) and a ventricle. The heart contains only the venous or deoxygenated blood. Red blood corpuscles are nucleated. There are two lateral lines which are sense organs, running one on either side of the body, which itself is streamlined. 10 pairs of cranial nerves present. The skin is generally covered with scales.

Class Pisces is sub-divided into two subclasses : (i) *Elasmobranchii* or *Cartilaginous* fishes and (ii) *Osteichthyes* or bony fishes, based on the nature of the internal skeleton.

Sub-Class—Elasmobranchii

(1) They are all marine forms with a cartilaginous endoskeleton.

(2) The mouth is ventral and provided with jaws bearing many rows of teeth.

(3) The nasal openings are ventral.

(4) The skin is covered with minute scales (Placoid).

(5) Gill slits are 5 to 7 pairs, opening to the outside separately without any covering or operculum.

(6) The tail fin has a dorsal lobe which is larger than the ventral (Heterocercal).

(7) In male, pelvic fins bear claspers for copulation.

Examples. Sharks (dog-fish or scoliodon), Ray fishes (Electric ray, sting ray), Saw fish, Hammer-headed shark (Fig. 59).

Shark. (Dog-fish or Scoliodon). (Fig. 58). It has a streamlined body, compressed laterally. The head is flat, the mouth ventral, and there is a pair of nostrils which are ventral to the snout. The eyes are at the sides. There are five pairs of gill-slits at the sides of the body. The fins are the organs of locomotion. There is a pair of pectorals, a pair of pelvics and two dorso-median fins, one ventral or anal fin and a tail or caudal fin. The skin is rough due to the presence of spine-like scales—the placoid scales.

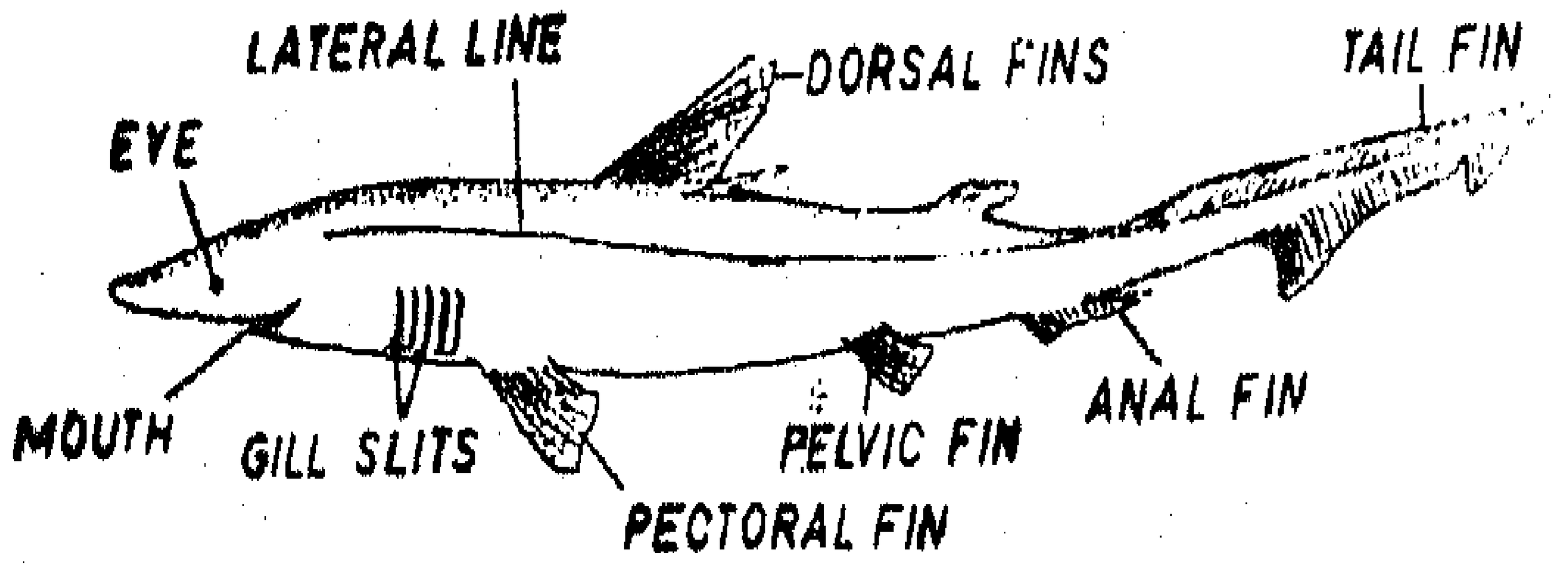


Fig. 58. *Shark (Scoliodon)*

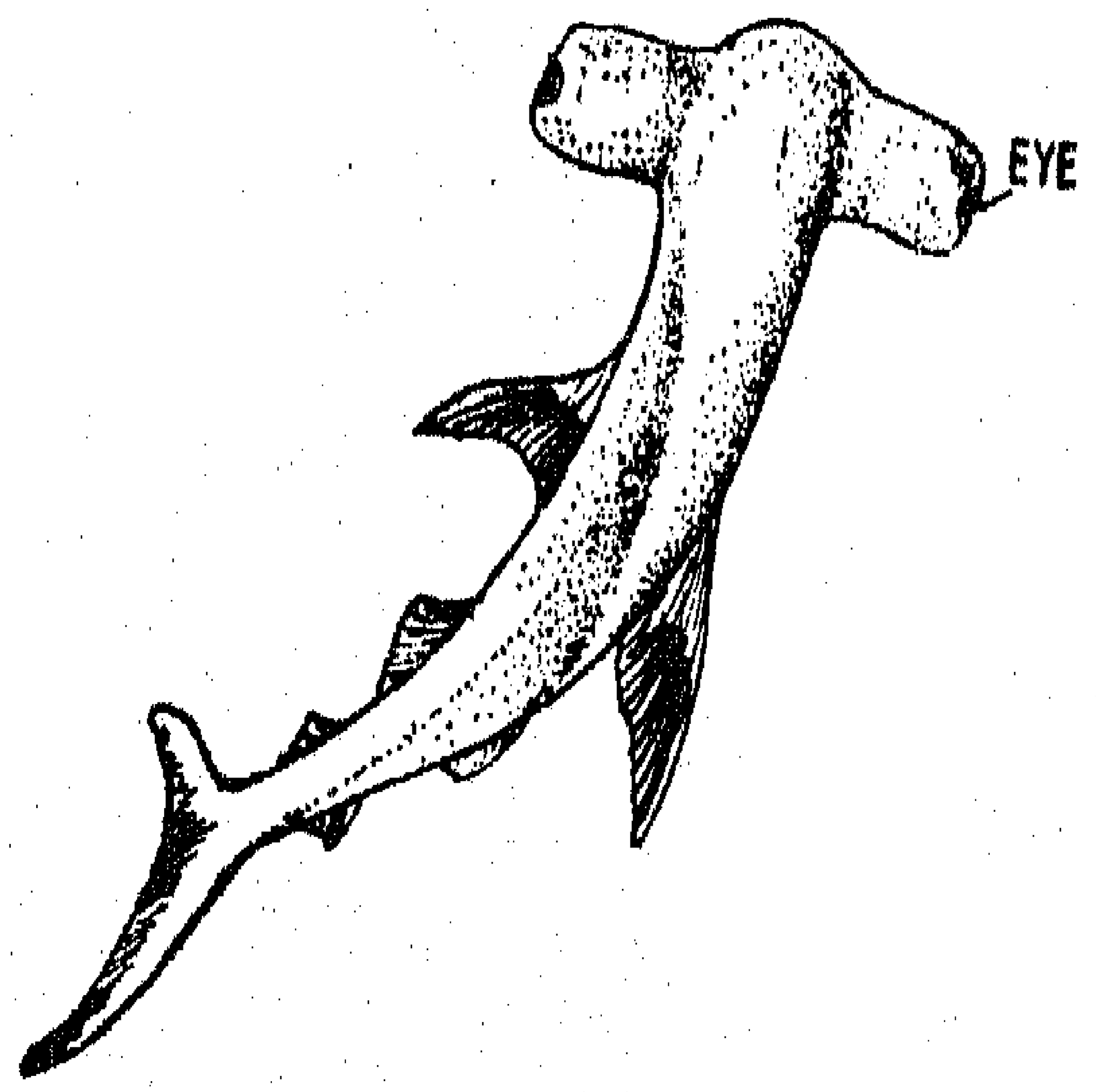


Fig. 59. *Hammer-headed Shark*

The skeleton is entirely made up of a substance called cartilage, which is flexible. Sharks grow to a great length (even up to 50 ft.), and are dangerous to swimmers in the sea. They are known for shark liver oil which is a very rich source of vitamin A.

Skates and Rays. Their bodies are flattened dorso-ventrally with the lateral expansion of the pectoral fins of the body. The posterior part of the body is reduced to a whip-like tail.

Electric ray. (Torpedo) (Fig. 60). It possesses a pair of electric organs, present between the pectoral fins. These are the modified muscles and are capable of giving severe electric shocks.

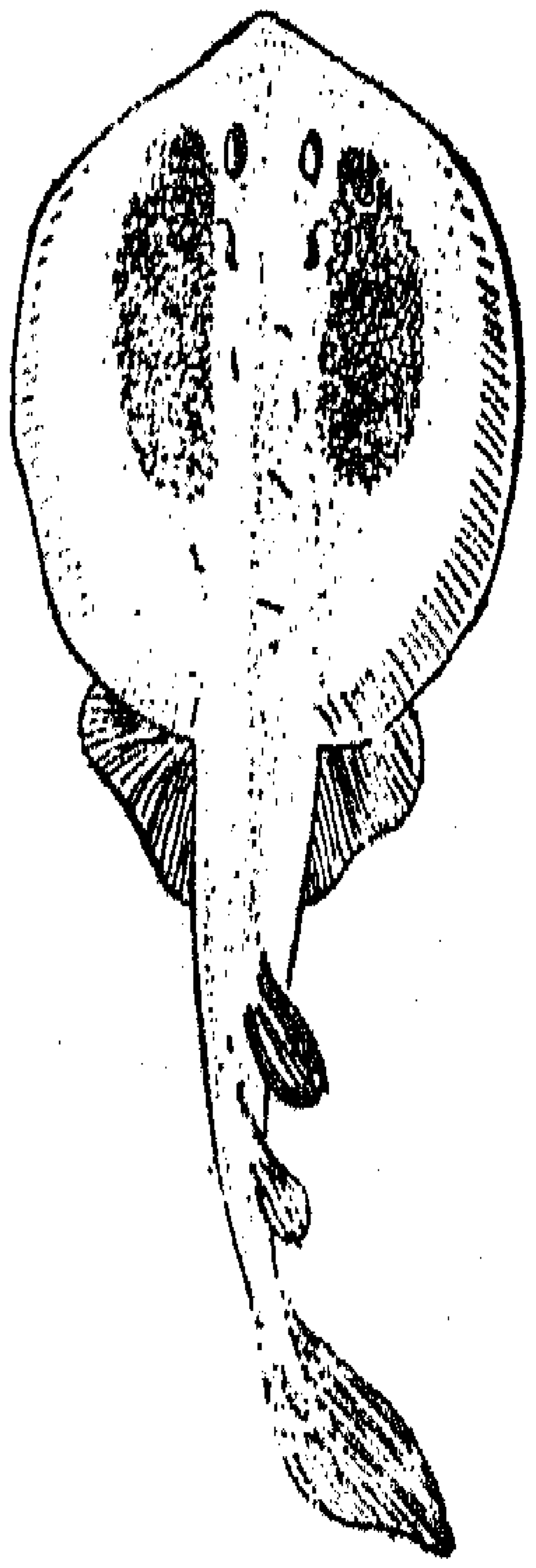


Fig. 60 *Electric Ray*

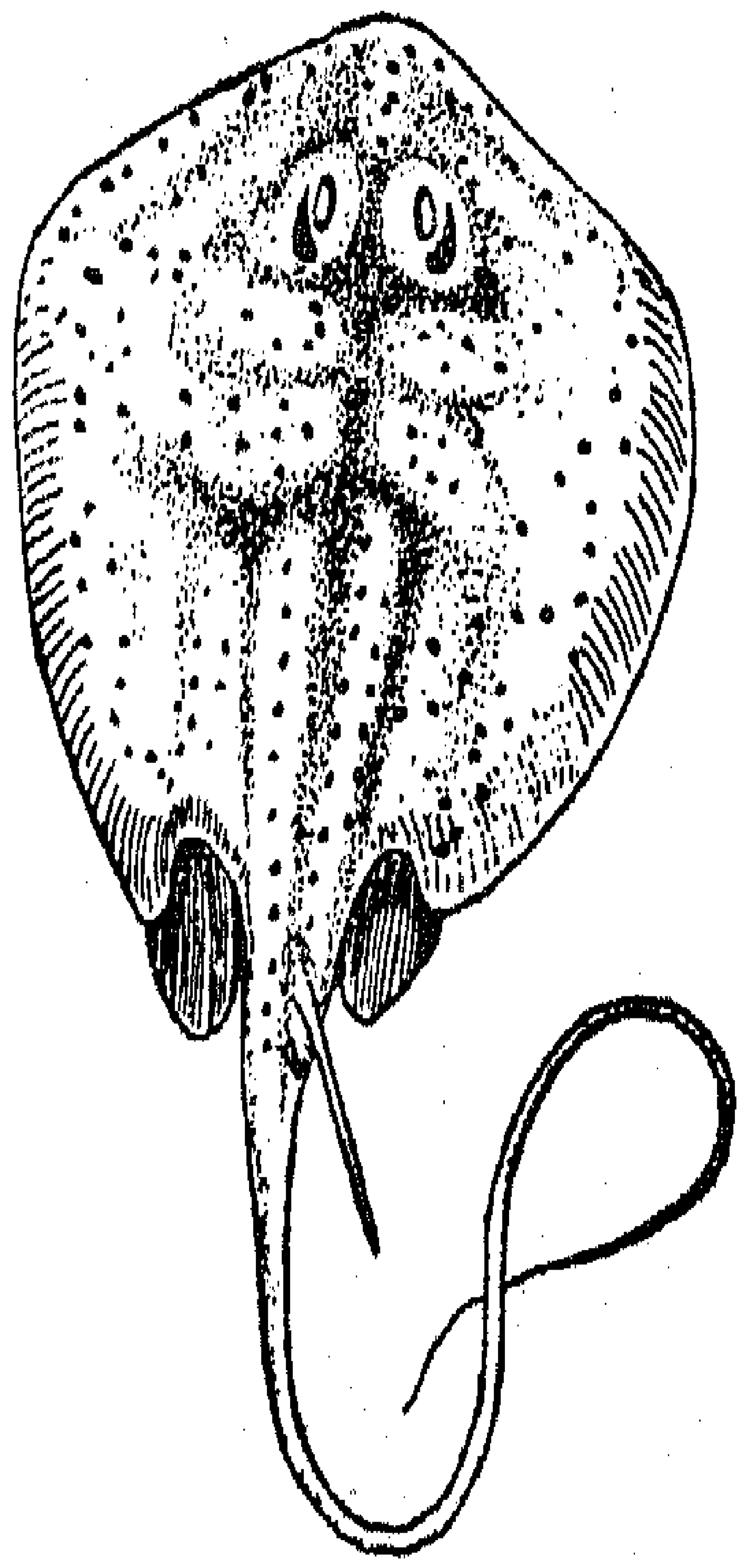


Fig. 61 *Sting Ray*

Sting ray. (Fig. 61). It has a long tail, at the base of which one or more spines (modified dorsal fin) are present, which can inflict severe wounds and are poisonous.

Sub-Class—Osteichthyes (Bony Fishes) (Fig. 62)

(1) They possess a bony skeleton.

(2) The mouth is terminal with teeth.

(3) The nasal openings are dorsal.

(4) The skin is covered by dermal scales of different types, namely, ganoid, cycloid or ctenoid.

(5) Respiration is by gills borne on bony arches, in a common chamber on either side of the pharynx, and covered by a bony lid or operculum.

(6) The tail fin has both the dorsal and the ventral lobes equally developed (Homocercal).

(7) There is usually an air (swim) bladder in the abdominal cavity, which serves as a hydrostatic organ. It develops as an outgrowth of the alimentary canal.

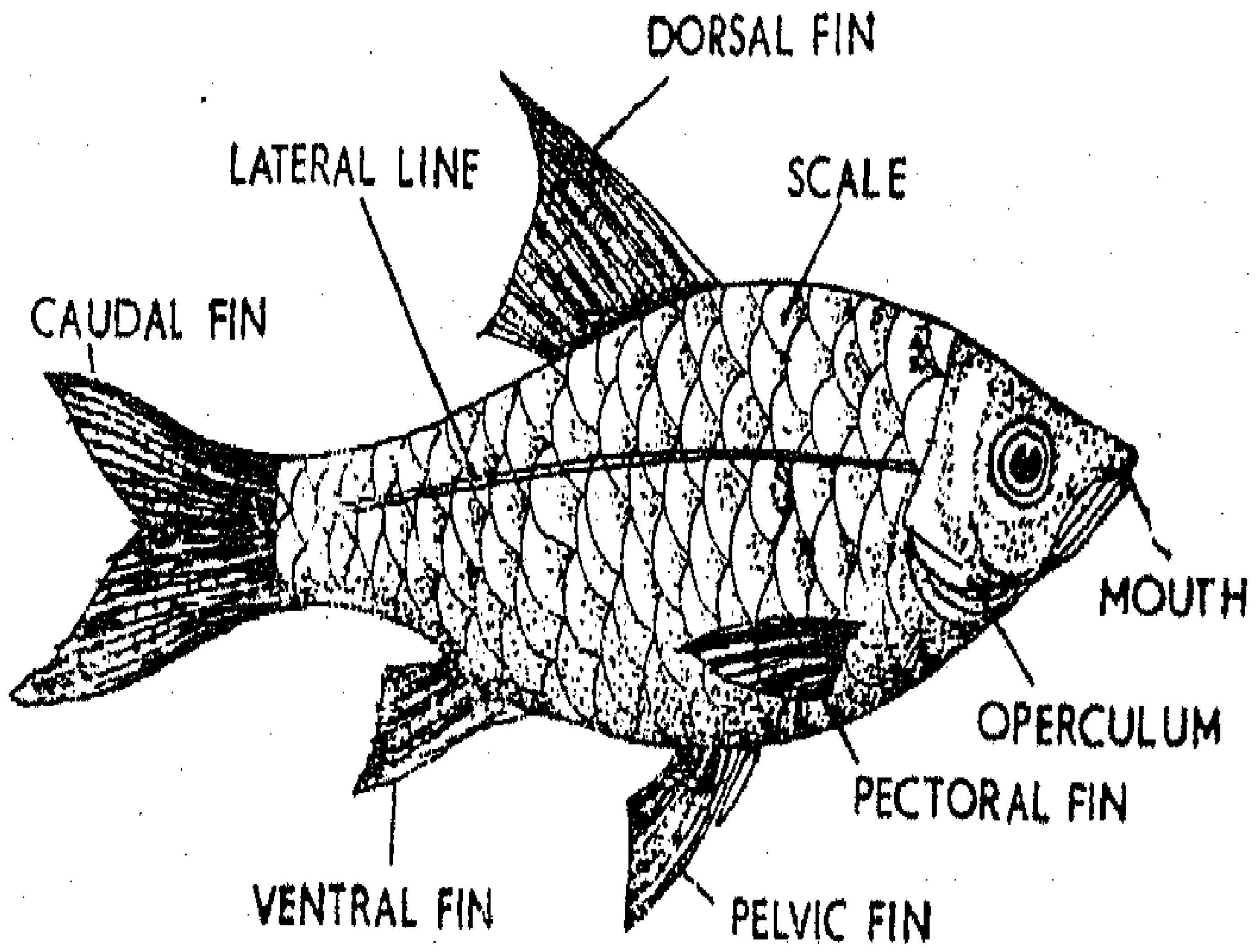


Fig. 62. *Bony Fish*

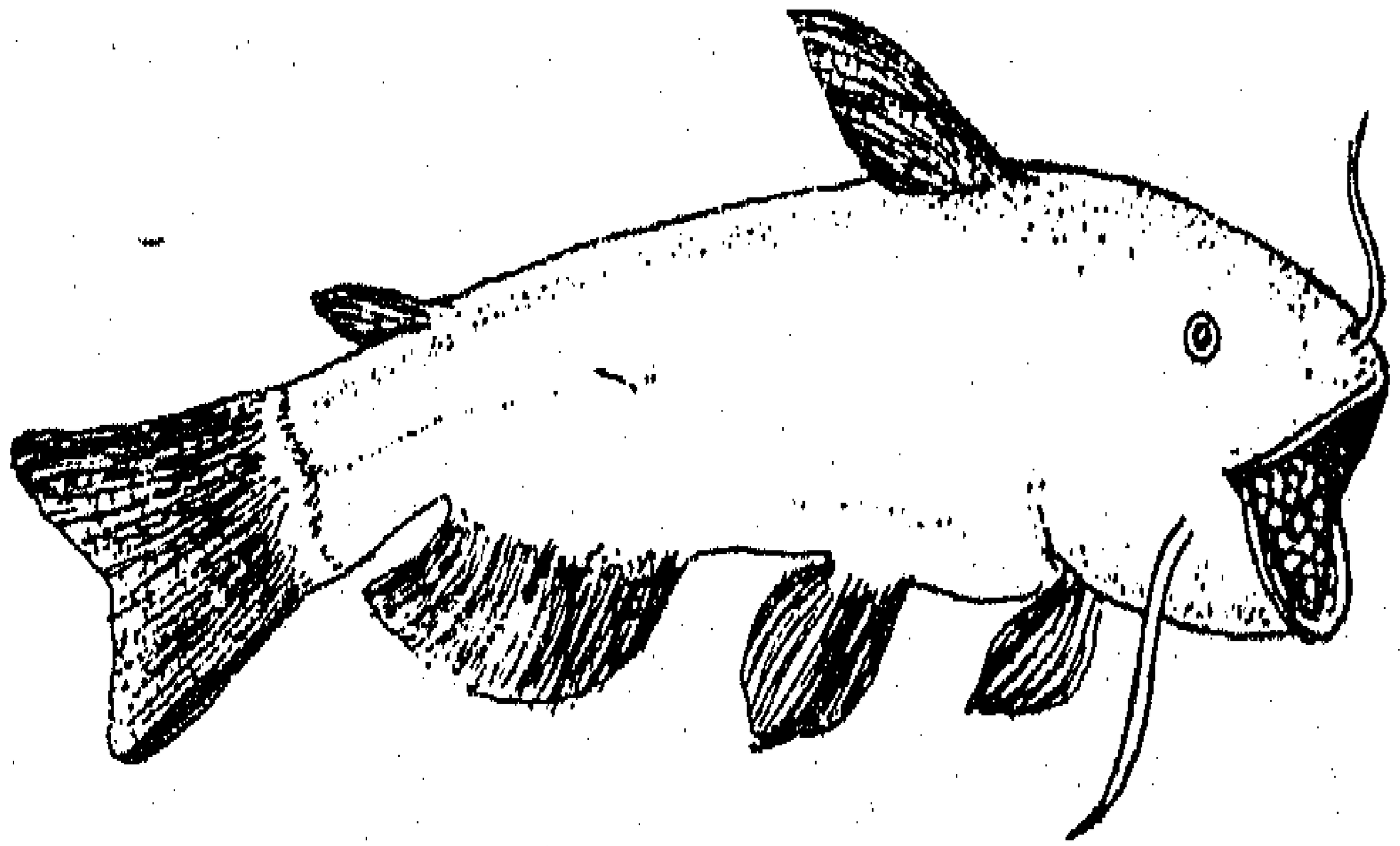


Fig. 63. *Cat fish*

Fishes are of great economic importance to man, for they form an important source of food. They are also the sources of liver oils having high contents of vitamins A and D. Glue is also manufactured from fish scrap after the extraction of oil. *e.g.*, Cat fish, flat fish, Eel, Flying fish, Sea-horse.

Cat fish. (Fig. 63) It has sensory barbs around the mouth. The body is either naked (scaleless) or with bony plates. A few species are in fresh water, others in salt water. The males look after the fertilized eggs, until they are hatched, by carrying them in the mouth.

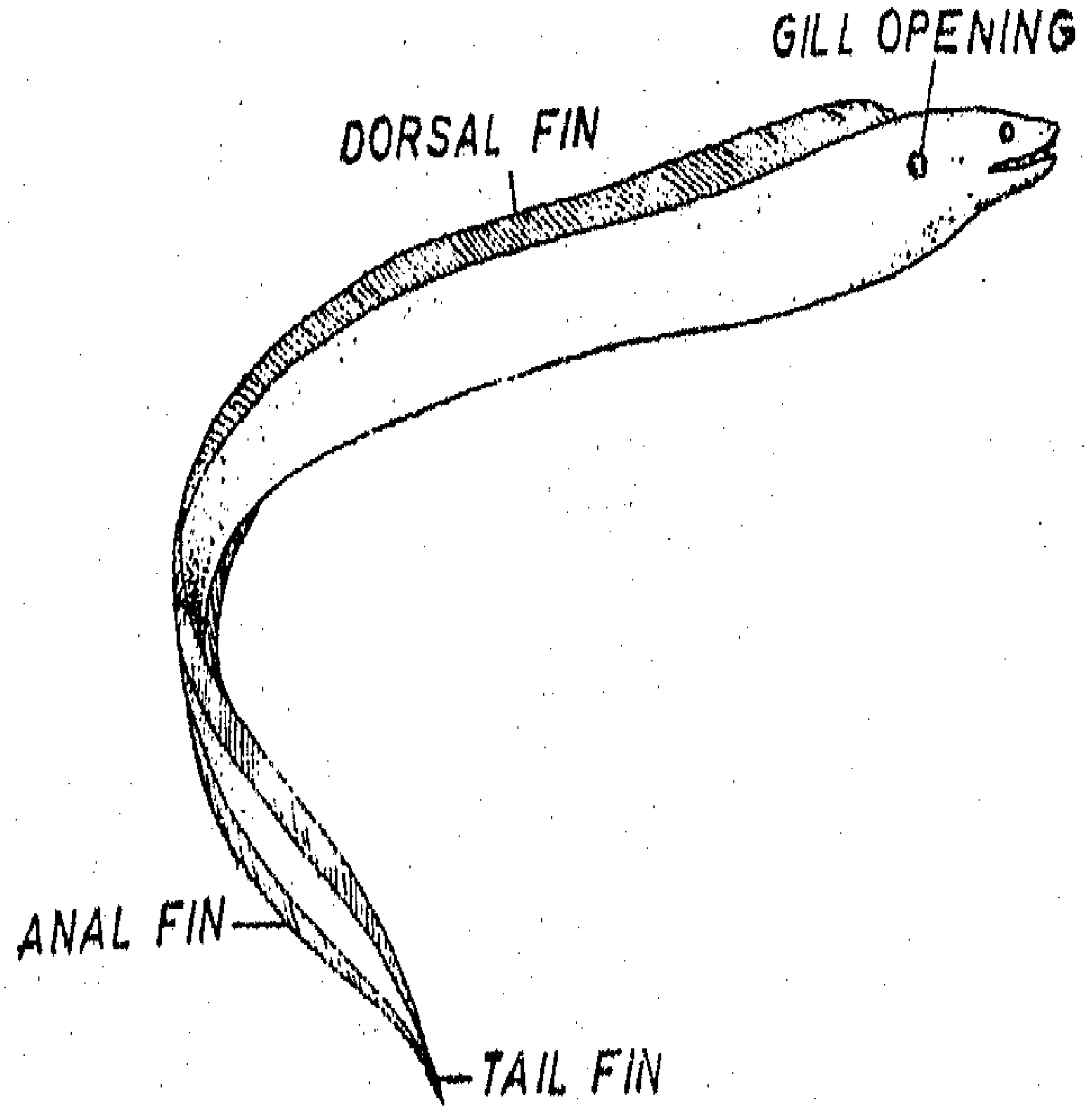


Fig. 64. *Eel*

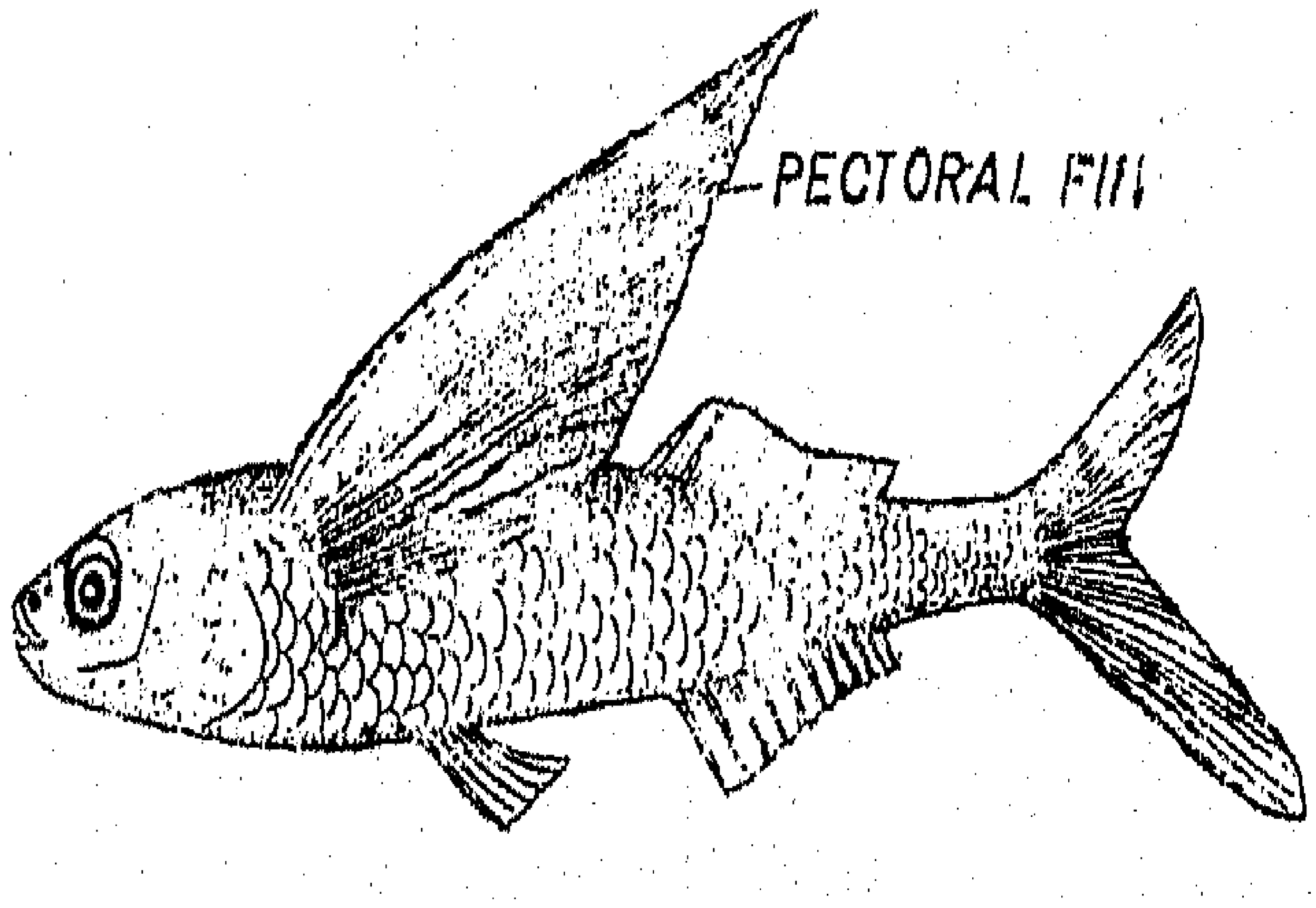


Fig. 65. *Flying Fish*

Eel. (Fig. 64) The body is elongated and appears like that of a snake. The scales are absent or rudimentary. Dorsal, caudal and anal fins are continuous, and pelvic fins usually absent. The gill openings are small.

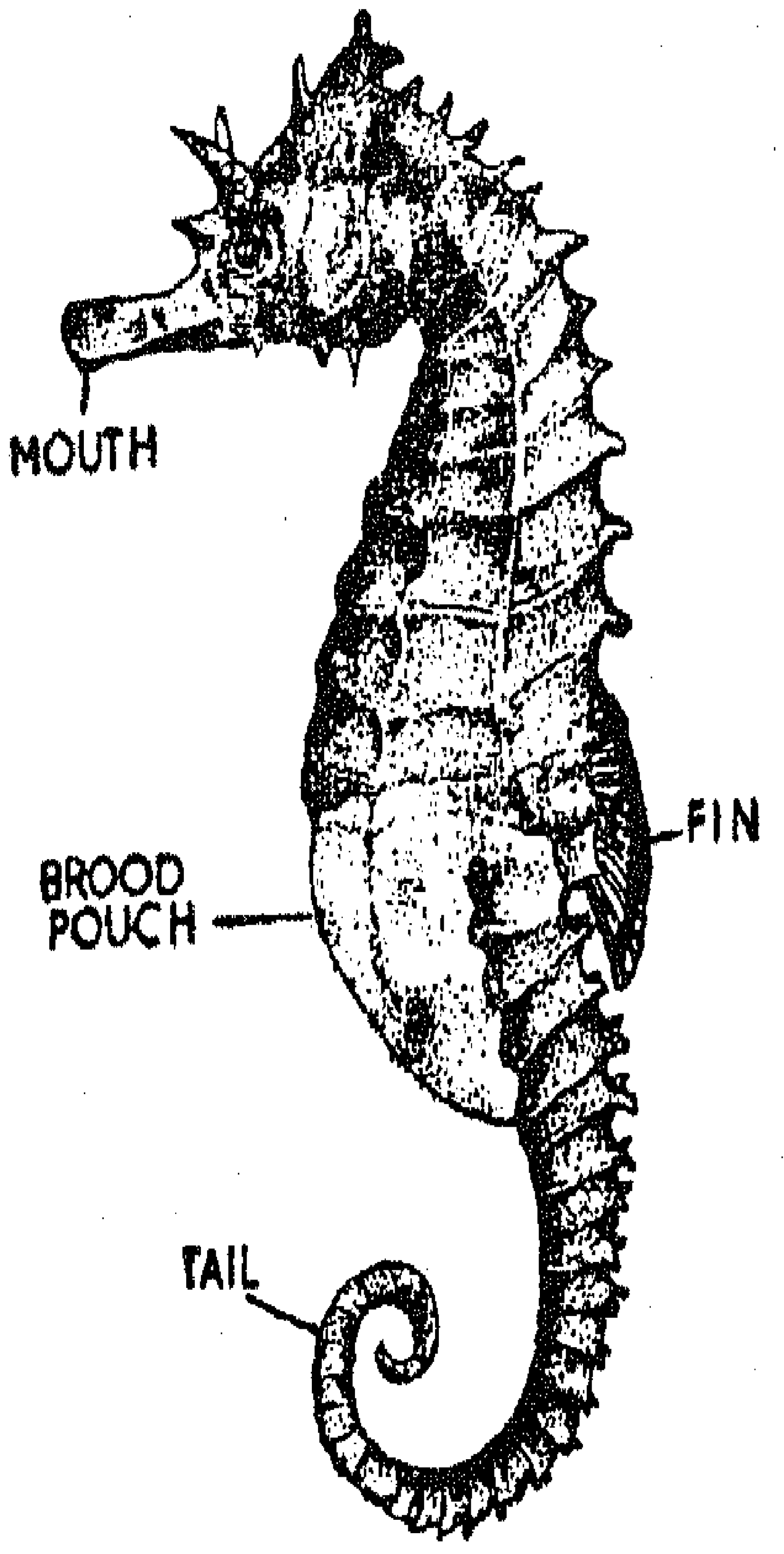


Fig. 66. *Sea-horse*

Flying fish. (Fig. 65) They have well developed pectoral fins which are placed high up in the body. They leap above the surface of the water to glide in air over water.

Sea-horse (Hippocampus): (Fig.66) The mouth is at the end of a tubular snout. The body is covered with bony rings. The head is enlarged and is at right angles to the body. It has a curved prehensile tail. The fish swims in a vertical position by the movements of the dorsal fin. The male usually possesses a brood pouch under the tail, in which eggs are sheltered until they are hatched.

Class-Amphibia

The amphibia lead a double life, living equally well in water as well as on land. In their larval condition, they are purely aquatic; while as adults they either live in water or can come out on land. Like the fishes, they are cold-blooded. They have two pairs of limbs, with digits (the caecilians are without limbs, while the sirens have only the hind limbs).

The skin is moist and glandular without any scales (except in caecilians). The nostrils are connected to the mouth cavity thus useful in respiration, and the eyes are provided with eyelids. The ear drum or tympanic membrane is external, covering the middle ear. The heart is three-chambered, with two auricles and a single ventricle. The sinus venosus opens into the right auricle. A pair of aortic arches is present. Red blood corpuscles are nucleated and oval. Respiration is by gills, lungs, skin, or by the lining of the buccal cavity. There are ten pairs of cranial nerves (nerves given from brain). The animals are mostly oviparous; and their development is through metamorphosis, involving an intermediate larval form (Tadpole); *e.g.*, Salamanders, Newts, Toads and Frogs.

Frog. The common Indian Frog is Rana tigrina. (Fig. 67) It is found abundantly in the rainy season in or near fresh water ponds, lakes, and streams. In winter, it buries itself in mud at the bottom of a pond and remains quiescent, with the life processes at their lowest ebb, until the onset of the rainy season, when once again it becomes active. This winter-sleep is called *hibernation*. The skin is smooth and moist, and provided with mucous glands and poison glands. The food of frogs consists of worms, slugs, insects and small fishes. The frog catches its food by throwing out its extensible sticky tongue with great rapidity. The tongue is attached in front to the lower jaw, and its free tip is bilobed or bifid. The body of the frog is dorsoventrally flattened and divisible into head

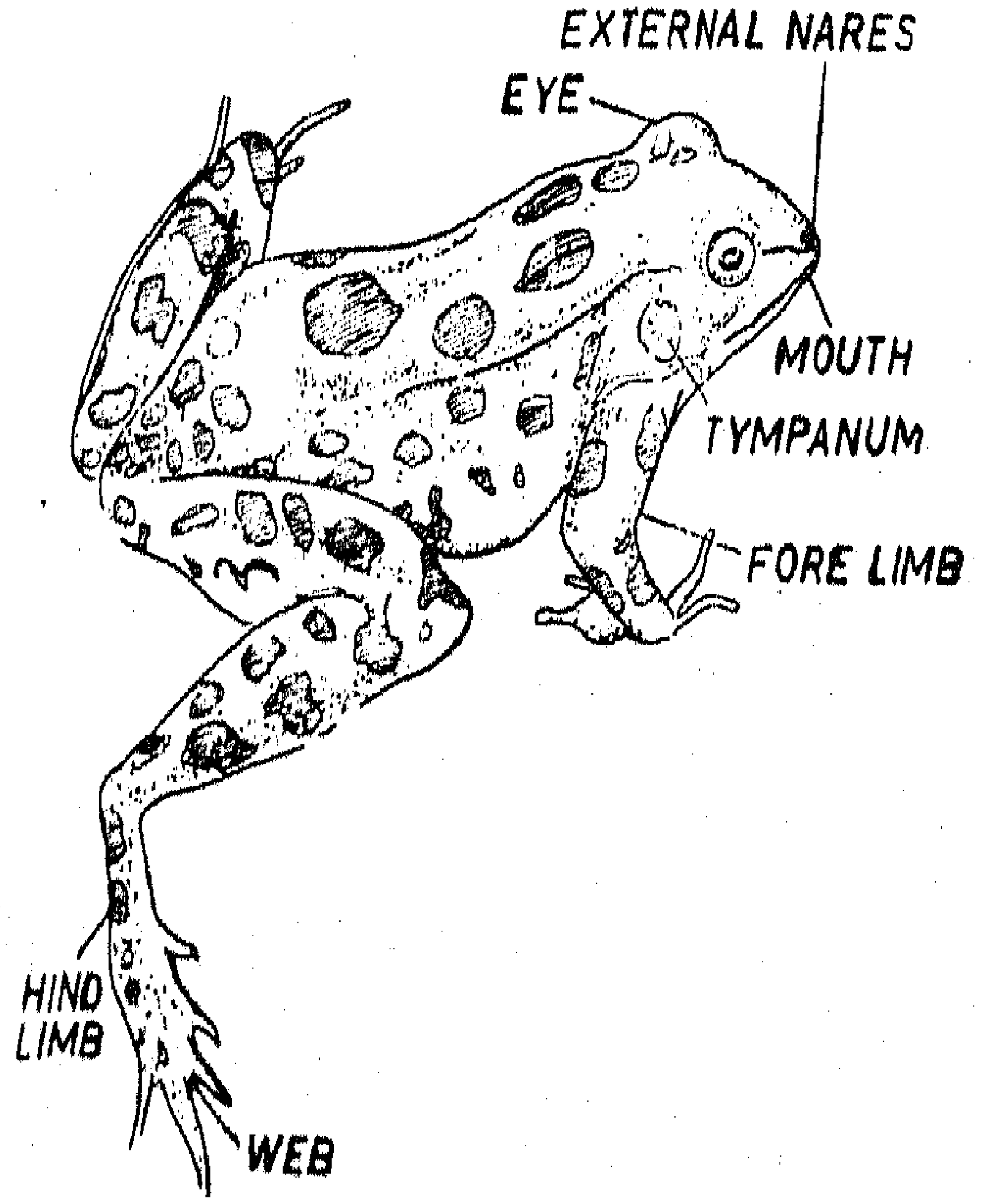


Fig. 67. *Frog*

and trunk. There is no neck. It has two pairs of limbs, the fore-limbs are short, while the hind-limbs are long and provided with webs between toes, and are used for leaping and swimming. There is no tail. The mouth is a wide opening at the anterior end of the snout. On the upper side of the snout is a pair of openings, the nostrils or external nares, which lead into the mouth cavity (buccal cavity). The eyes are large and protruding, and provided with an upper and lower eyelid. The lower eyelid is movable and is attached to a thin transparent membrane, the nictitating membrane, which can be drawn over the eye. A patch of membrane, called the tympanum, lies just behind the eyes.

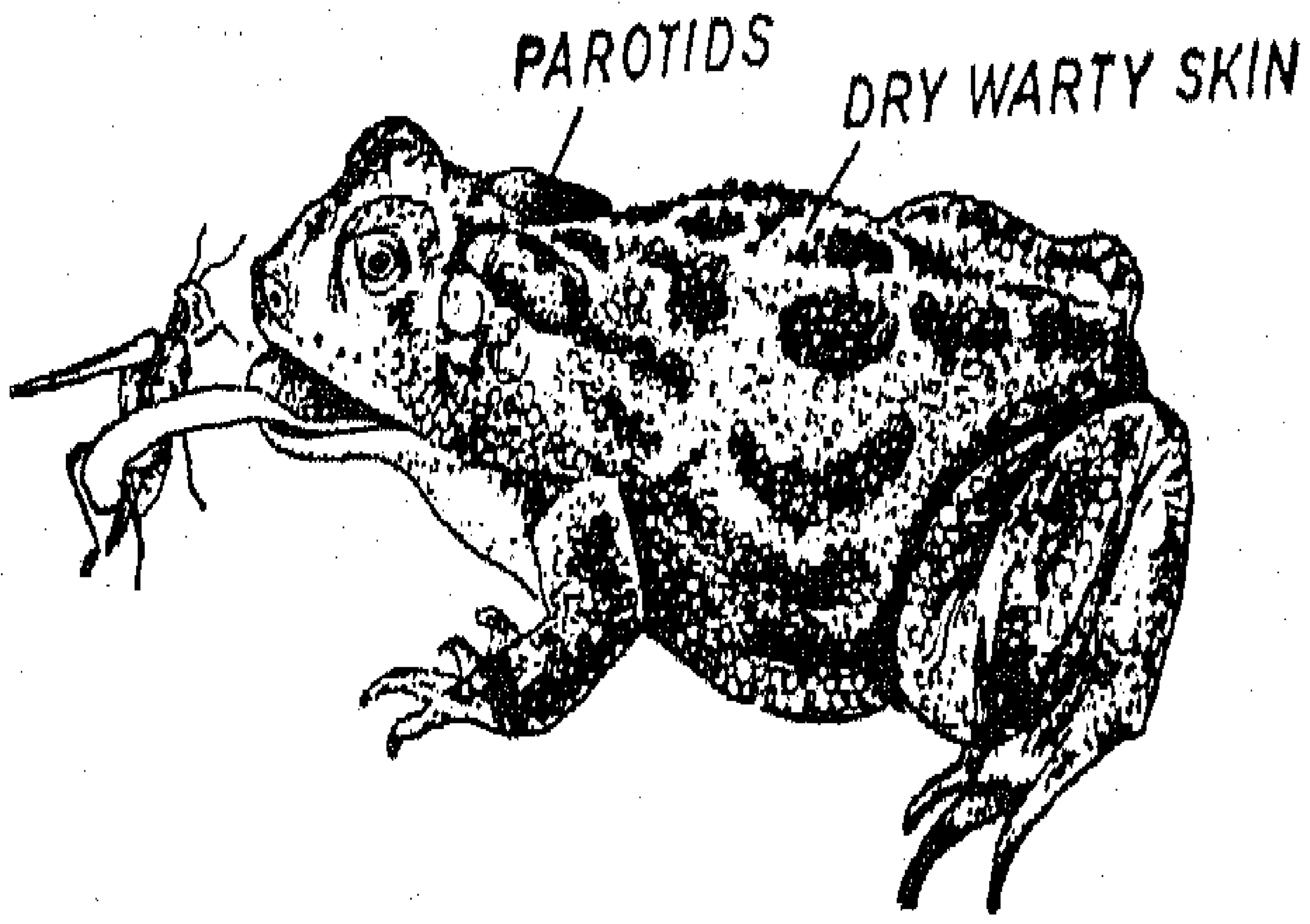


Fig. 68. *Toad*

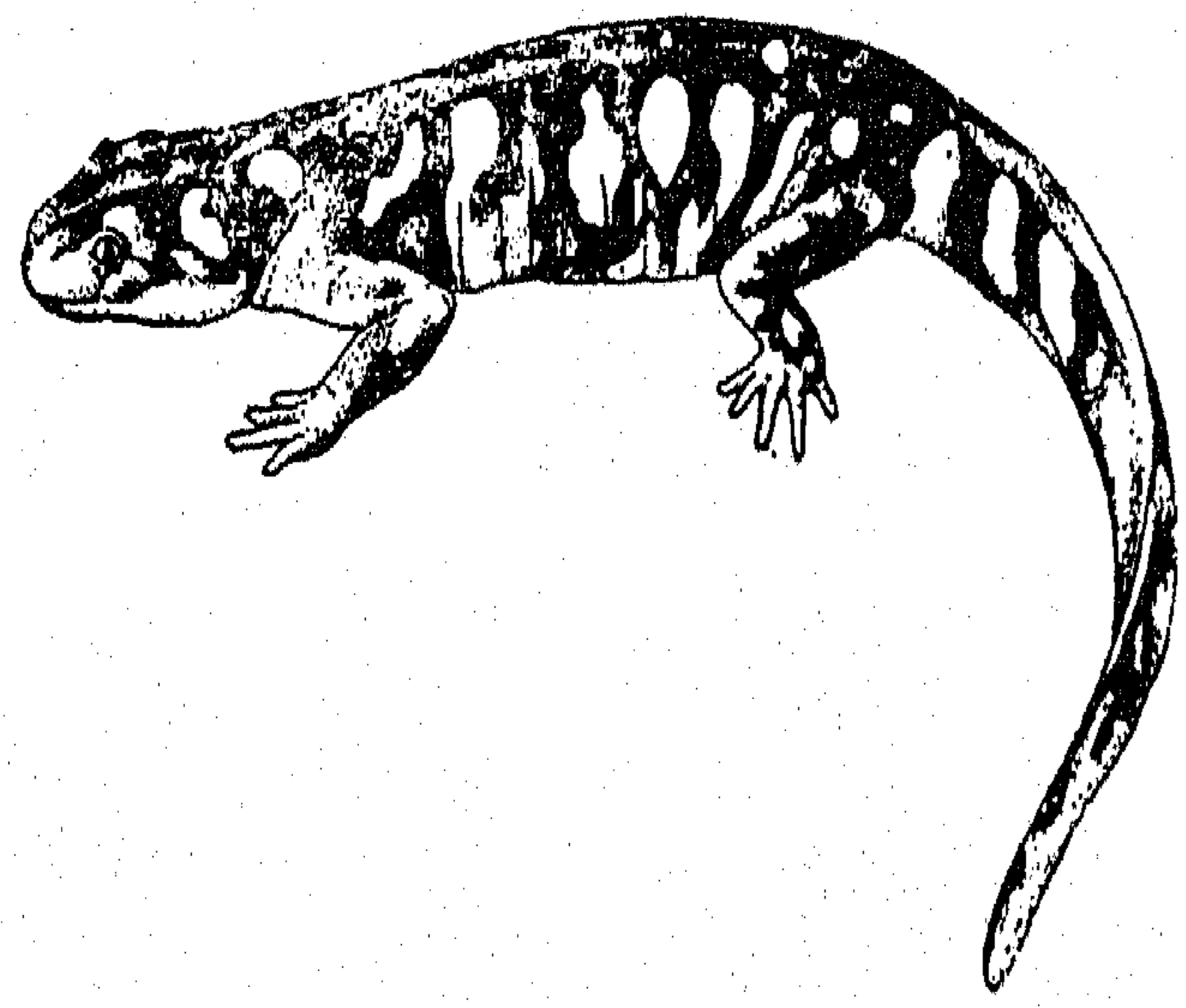


Fig. 69. *Salamander*

Toad (Bufo) (Fig. 68). It is like the frog in many respects but the skin is rough and is covered with warts. The web in the hind-limbs is greatly reduced.

Salamander (Fig. 69) **and Newts.** These are tailed amphibians that look like reptiles, but their skin is slimy and without scales. Some of them possess external gills even in adult condition, and tail fin.

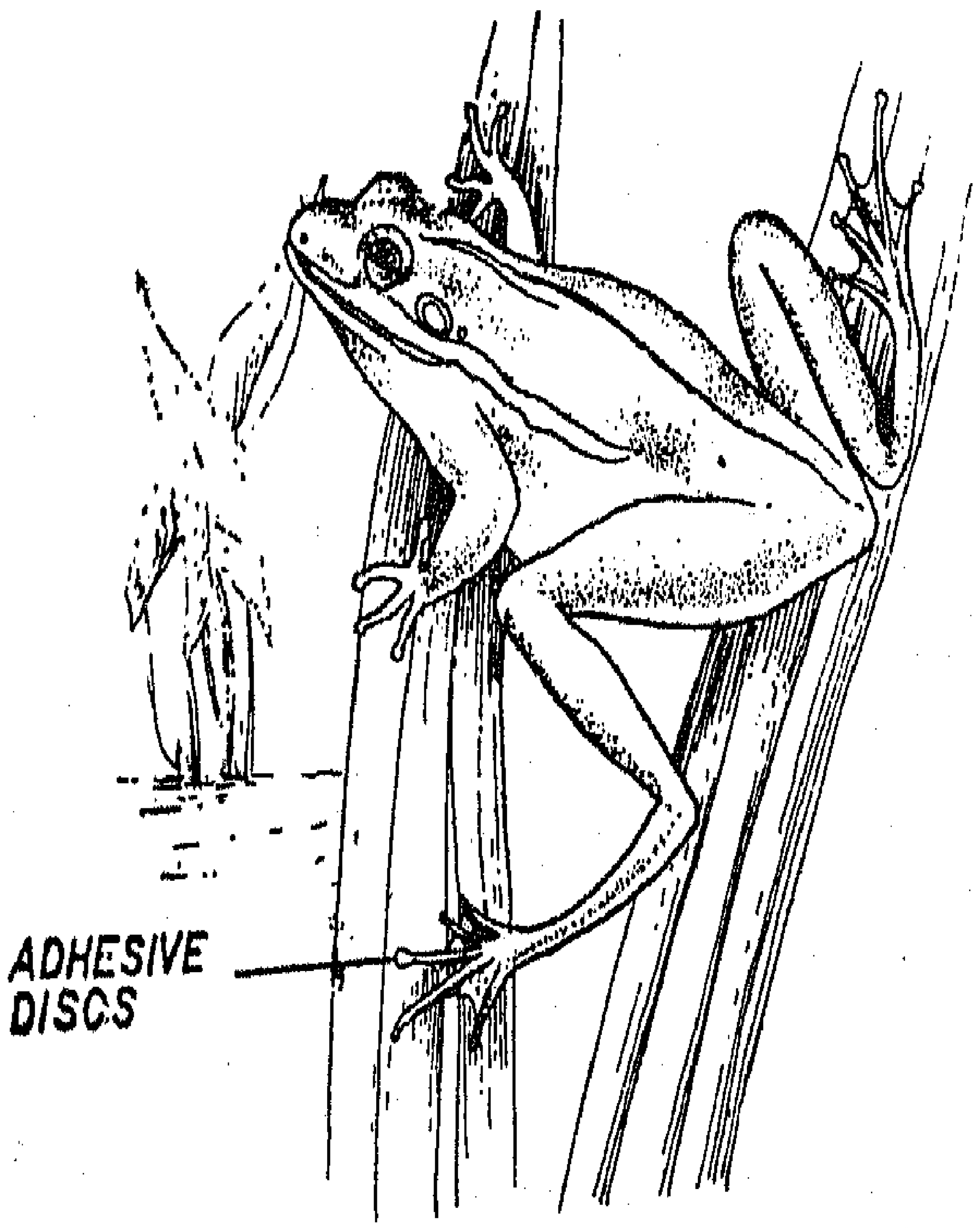


Fig. 70. *Hyla* (*Tree Frog*)

Tree frogs (Hyla) (Fig. 70) They are mostly small-sized, under 2 inches. All fingers and toes have expanded adhesive discs at their tips, which are used as sucking pads for climbing on trees.

Class-Reptilia

Reptiles are cold-blooded air breathing vertebrates, which have adapted themselves completely to land. Some of the reptiles, however, have secondarily taken to water.

The skin is dry and horny, and covered with scales or bony plates (*i.e.,* scutes). Normally, there are two pairs of limbs with

5 digits each, and each digit ending in a horny claw, but in some the limbs or claws or both are reduced, modified or lost (modified as paddles in turtles; lost in snakes). Respiration is by lungs. The heart is imperfectly 4-chambered, with two auricles and a partially divided ventricle (crocodiles have a fully divided ventricle, and thus have a perfect 4-chambered heart). The sinus venosus opens into the right auricle. There are two aortic arches. The red blood corpuscles are nucleated and oval. There are 12 pairs of cranial nerves. Eggs are laid after internal fertilization (*i.e.*, they are *oviparous*). A few snakes give birth to young ones (*i.e.*, they are *viviparous*). There is no metamorphosis (*i.e.*, no larval stage).

The living or modern reptiles include Turtles, Tortoises, Lizards, Snakes, Crocodiles and Alligators.

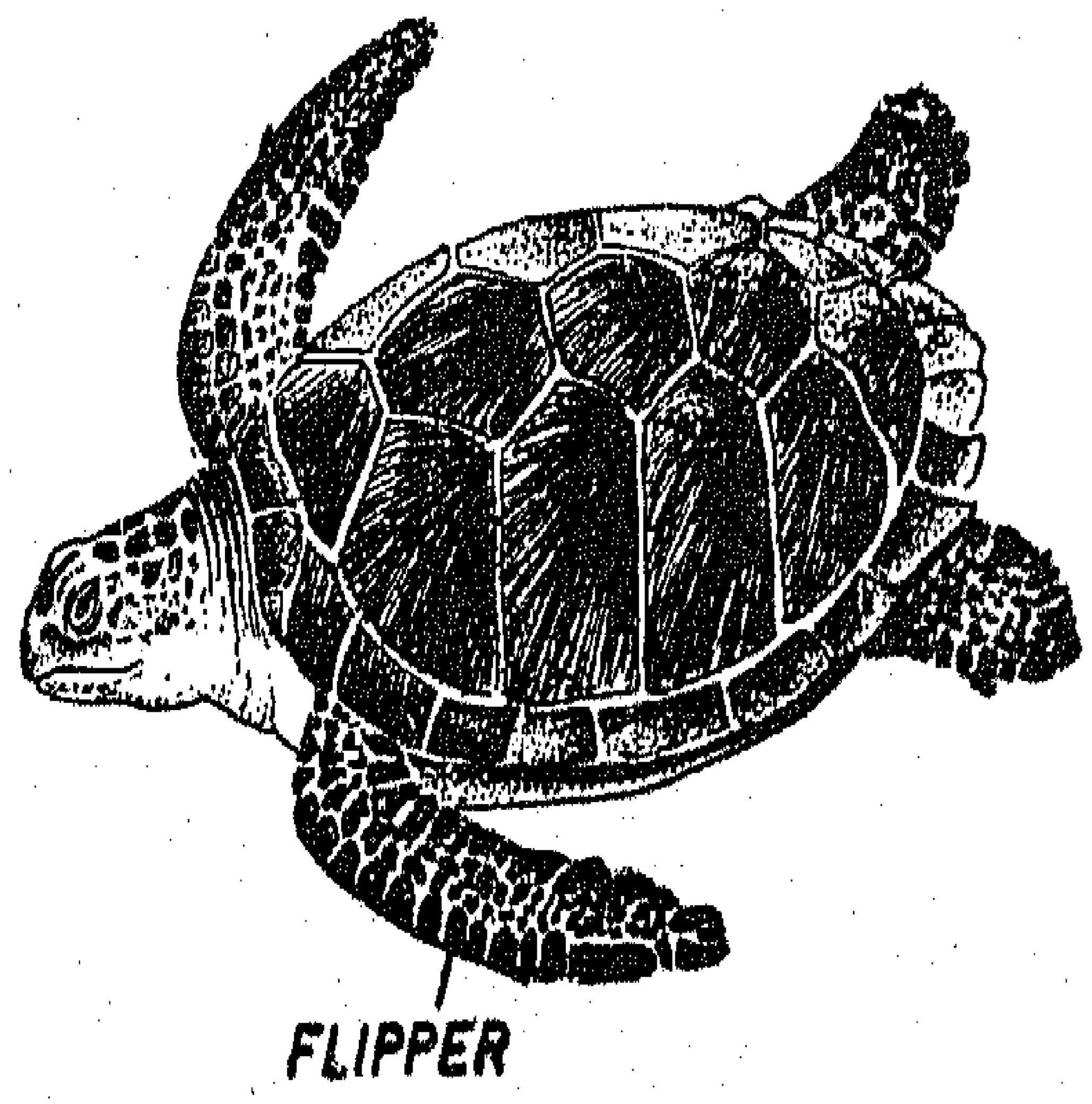


Fig. 71. *Turtle*

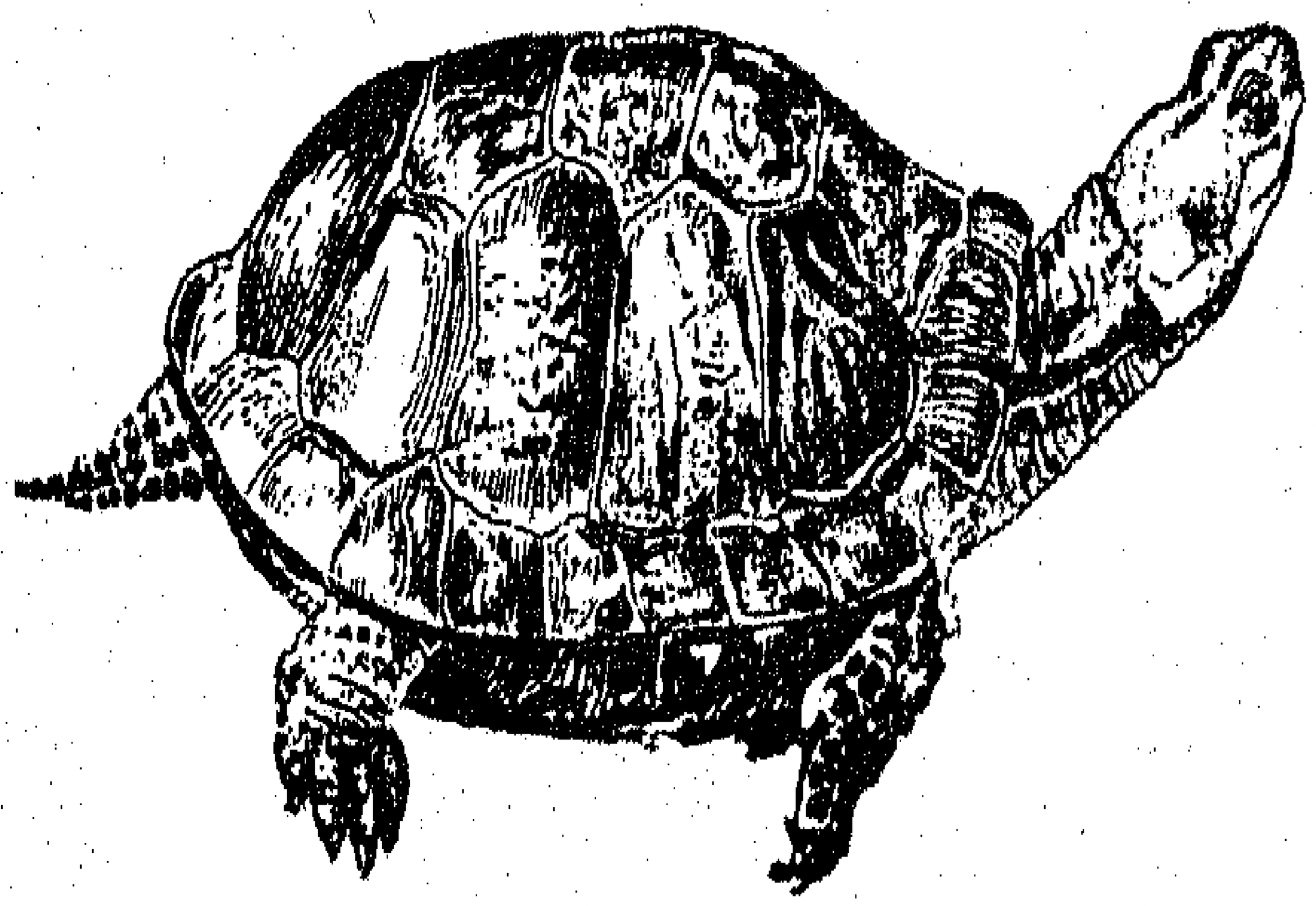


Fig. 72. *Tortoise*

Turtles and Tortoises. The body of the turtle is broad, enclosed in a hard shell which consists of a dorsal rounded carapace and a flat ventral plastron. The head, neck, tail, and limbs can be retracted into the shell. The jaws are without any teeth, but are covered with a horny sheath. They are oviparous, laying a large number of eggs in pits dug up by the females.

Turtles (Fig. 71) are aquatic, either fresh water or marine, and have their limbs modified into paddles for swimming. Tortoises (Fig. 72) are strictly terrestrial, and possess claws on their limbs.

Lizards

Garden lizard (Calotes). (Fig. 73). The body is slender with four limbs and a tail. The skin is usually covered with horny scales. The eyes have movable eyelids.

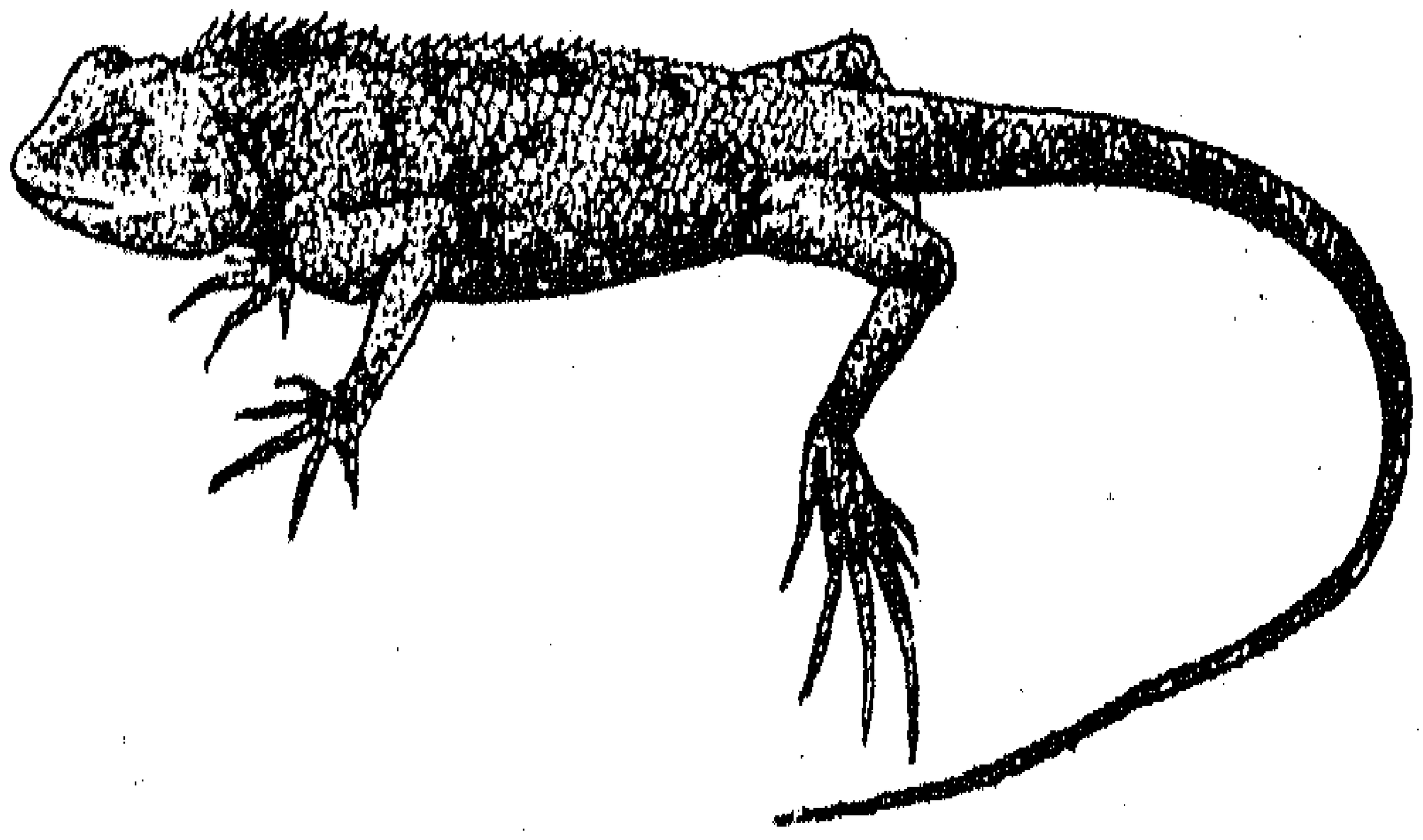


Fig. 73. *Garden lizard*

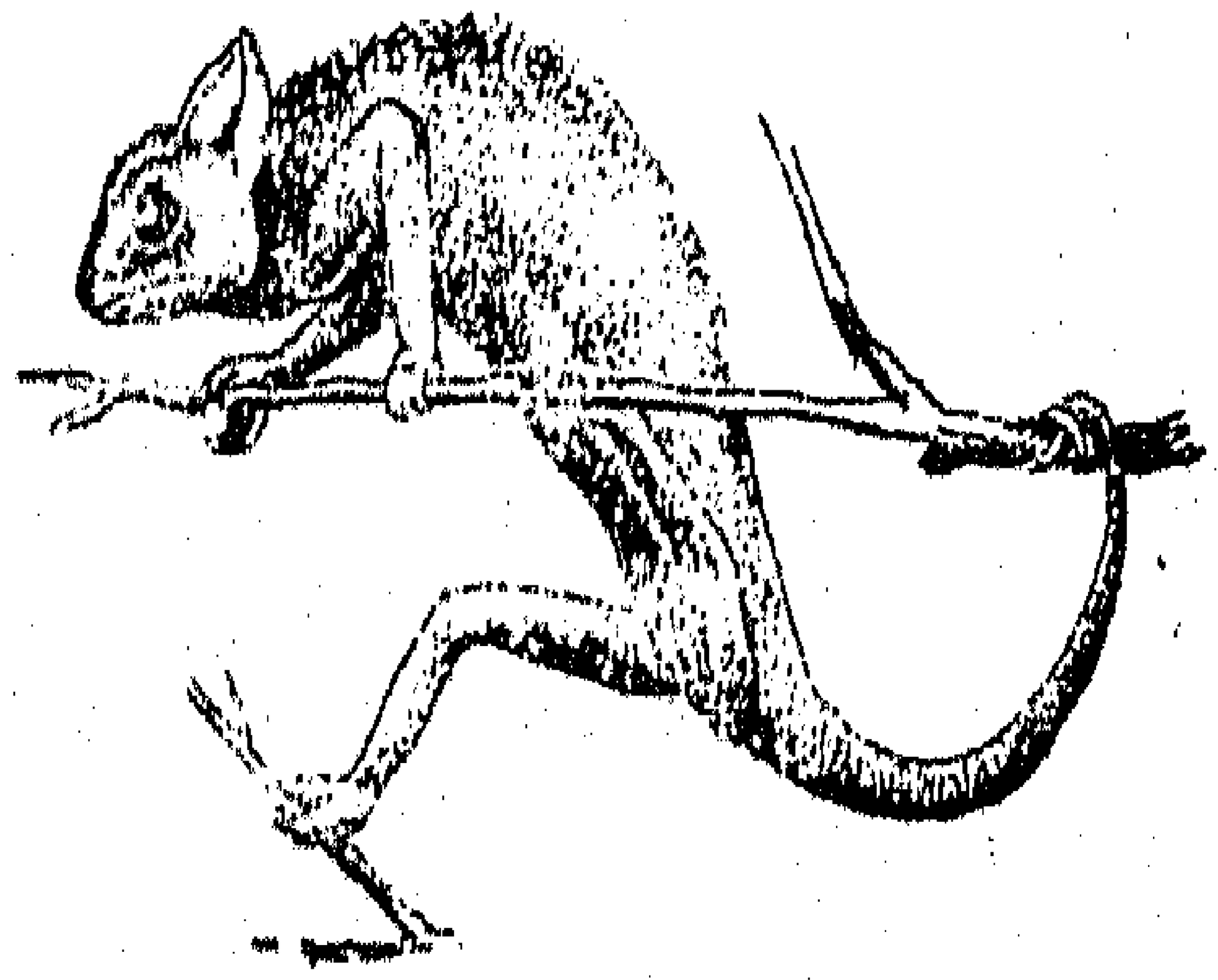


Fig. 74. *Chameleon*

Chameleon. (Fig. 74). The body is compressed from side to side with an angular head. The tail is long and prehensile. The limbs have opposable digits for grasping. The tongue is long and sticky. The chameleons are known for rapidly changing their colour to suit the surroundings in which they live.

Wall lizard. (Gecko) (Fig. 75). They live in houses and feed upon insects. They have rounded adhesive pads at the tips of their toes, which enable them to climb on smooth surfaces.

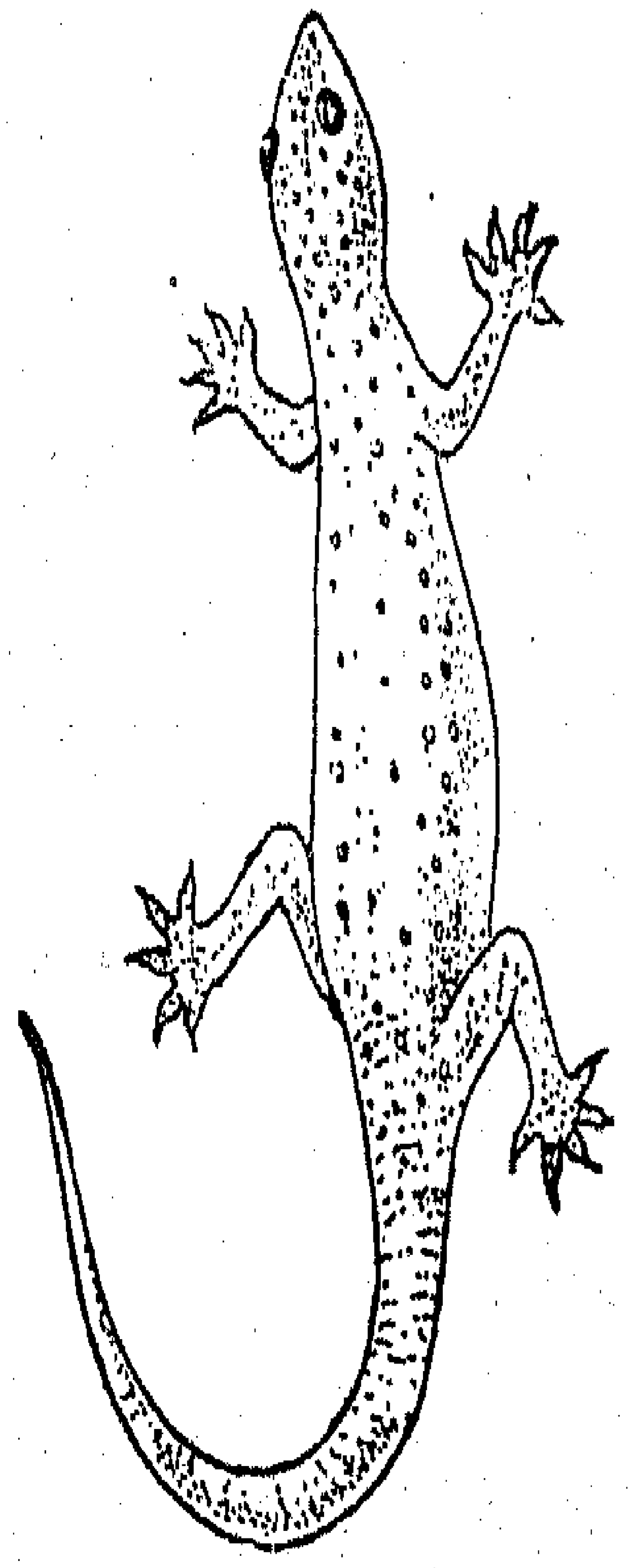


Fig. 75. *Wall lizard*

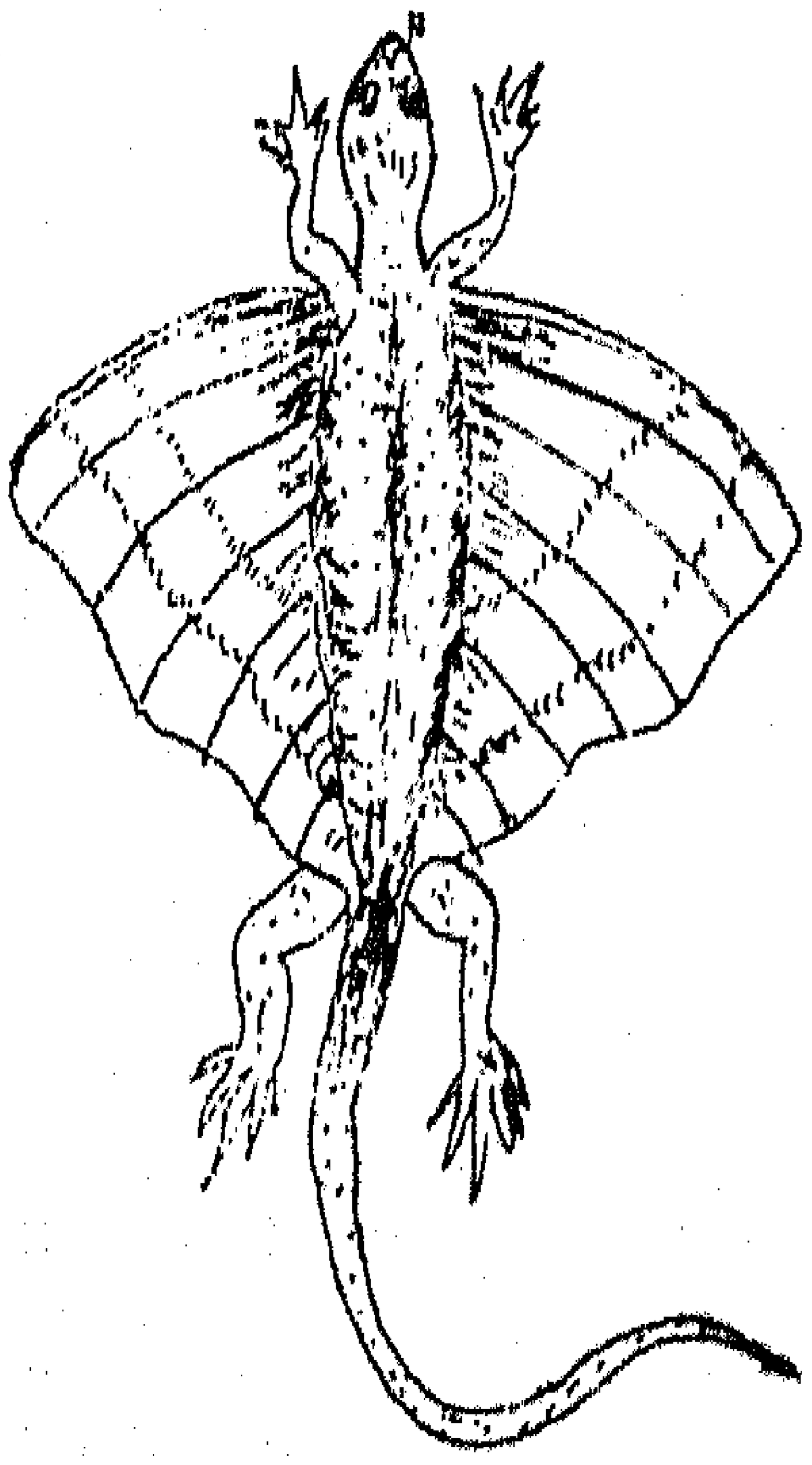


Fig. 76. *Flying lizard*

Flying lizard. (Draco). (Fig. 76). These are able to glide from one tree to the other by means of the lateral skin folds supported by ribs, in the form of patagium extending between the fore and hind limbs.

Snakes (Figs. 77 and 78). The body is elongated and cylindrical without any limbs. They have neither the external ear nor the eyelids. The body is covered with horny scales. The scales on the ventral side of the body do not overlap, but form broad transverse rows of plates which are used for creeping. The tongue is bifid. The majority of snakes are non-poisonous; only a few are poisonous. In poisonous snakes, the salivary glands are modified into poison glands. They have one or two pairs of teeth, which are grooved or perforated and are called *fangs*. The poison glands open into the fangs by their ducts. Through these fangs, the poison or *venom* is conducted into the wounds made by the fangs. The venom has a destructive effect on the red blood corpuscles. Poisons of some snakes affect the nervous system (*e.g.*, Cobra—Fig. 77). In non-poisonous snakes, the teeth are solid and without any groove. No poison glands are present.

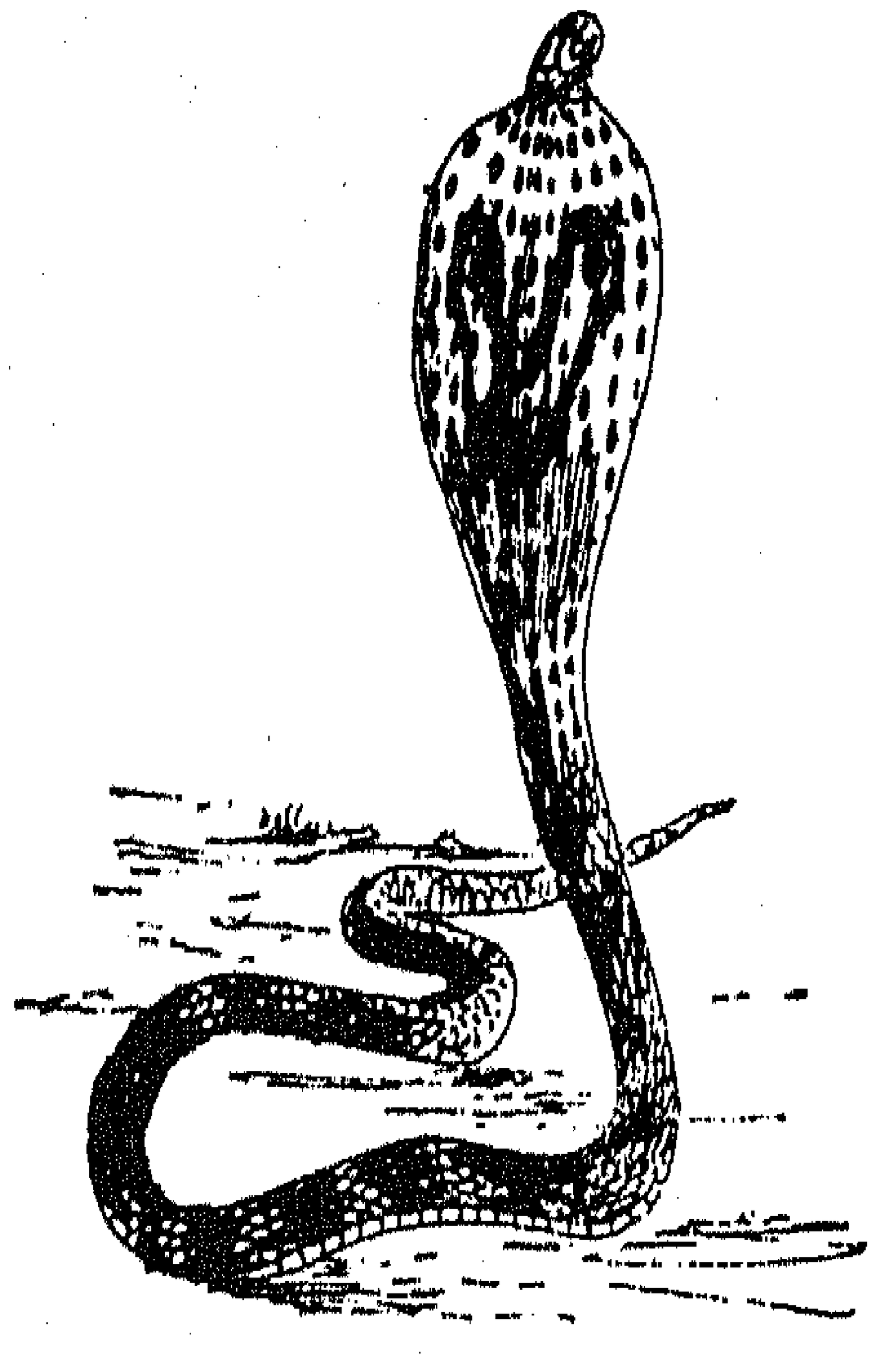


Fig. 77. *Cobra*

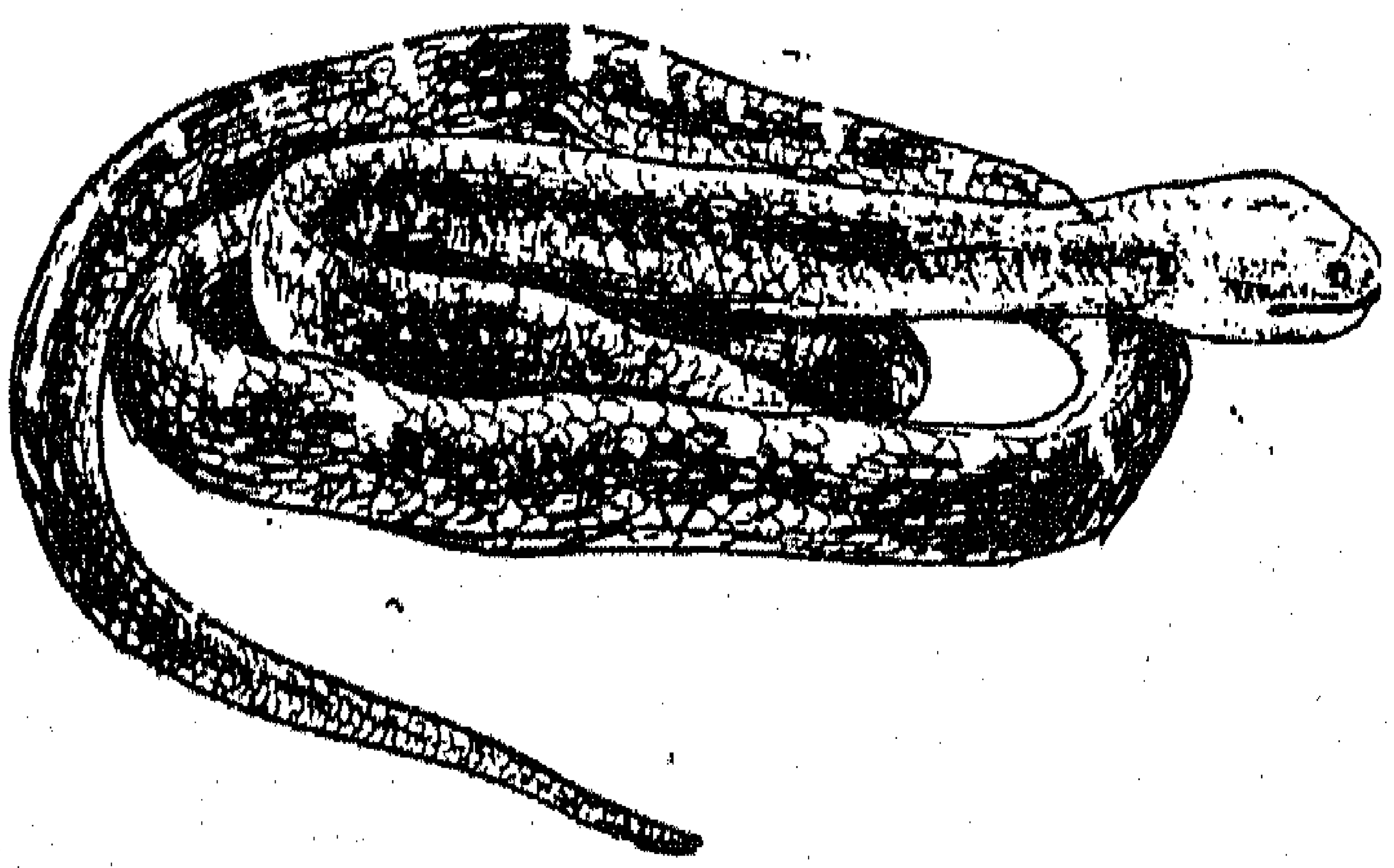


Fig. 78. *Snake*

The sea-snakes have a laterally compressed tail. All sea-snakes are very poisonous.

The cobra, krait and vipers are the common poisonous snakes.

Rat snake, tree snake and python are some of the non-poisonous snakes.

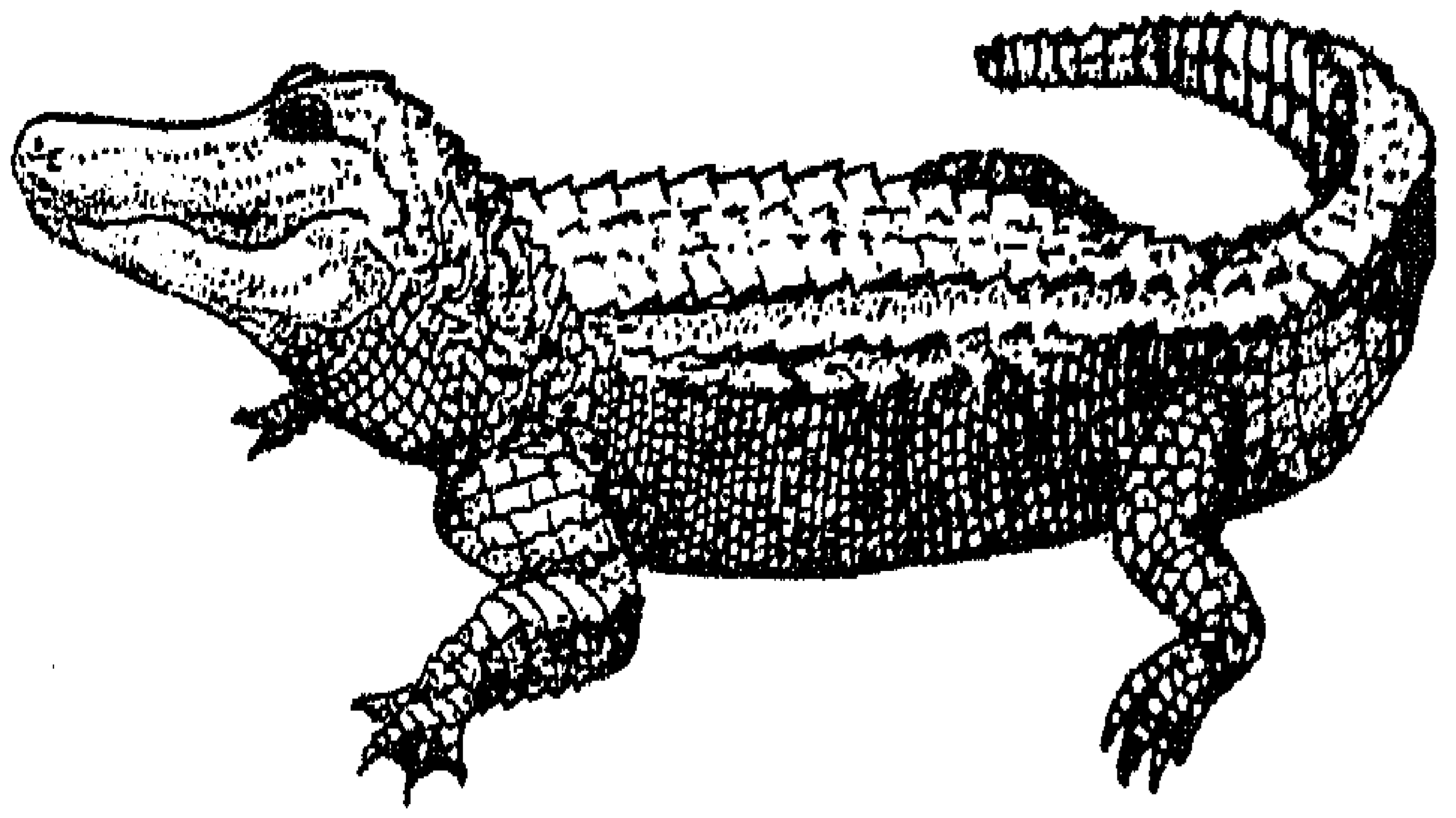


Fig. 79. *Crocodile*

Crocodile. (Fig. 79). It has a head and a long tail which is laterally compressed. Large horny scales with thick dermal bony plates beneath are present in the skin. The teeth are in sockets in the jaws. The heart has a completely partitioned ventricle and has two aortic arches.

Class—Aves

They are warm-blooded vertebrates (*Homoiothermal i.e.*, the body temperature is maintained at a particular normal, irrespective of the changes in the atmospheric temperature). They are successfully adapted for aerial life. They have a streamlined body. The body is covered with feathers, which serve to keep it warm and also aid in flight. These feathers are called *contour feathers*. No other vertebrates possess feathers. They have two pairs of limbs. The fore limbs are módified as wings for flight. The hind limbs are used for perching, walking or swimming. Each foot has usually 4 toes. The lower part of the leg is covered by scales. The bones are light, being hollow. The breast-bone (*Sternum*) has a keel, to serve as an attachment to the powerfully developed pectoral muscles that are used in the movement of the wing in flight. The head is prolonged into a beak, which is without teeth, but is horny. The heart is 4-chambered, with two auricles and two ventricles. There is no sinus venosus only one aortic arch present, *i.e.*, on the right side. The red blood corpuscles are nucleated and oval. Respiration is

by a pair of compact lungs attached to ribs and connected to thin-walled air sacs, which send extensions into the bones as well (thus making the bones pneumatic).

Near the bifurcation of the wind-pipe (*Trachea*) into two branches (*Bronchii*), the wind-pipe is modified into a voice-producing organ, the *Syrinx*. The ovary and the oviduct of only the left side are developed. No urinary bladder is present. Excretion is semi-solid. There are 12 pairs of cranial nerves. The birds lay eggs after internal fertilization; and they incubate the eggs till they are hatched. The young ones are taken care of by the parents.

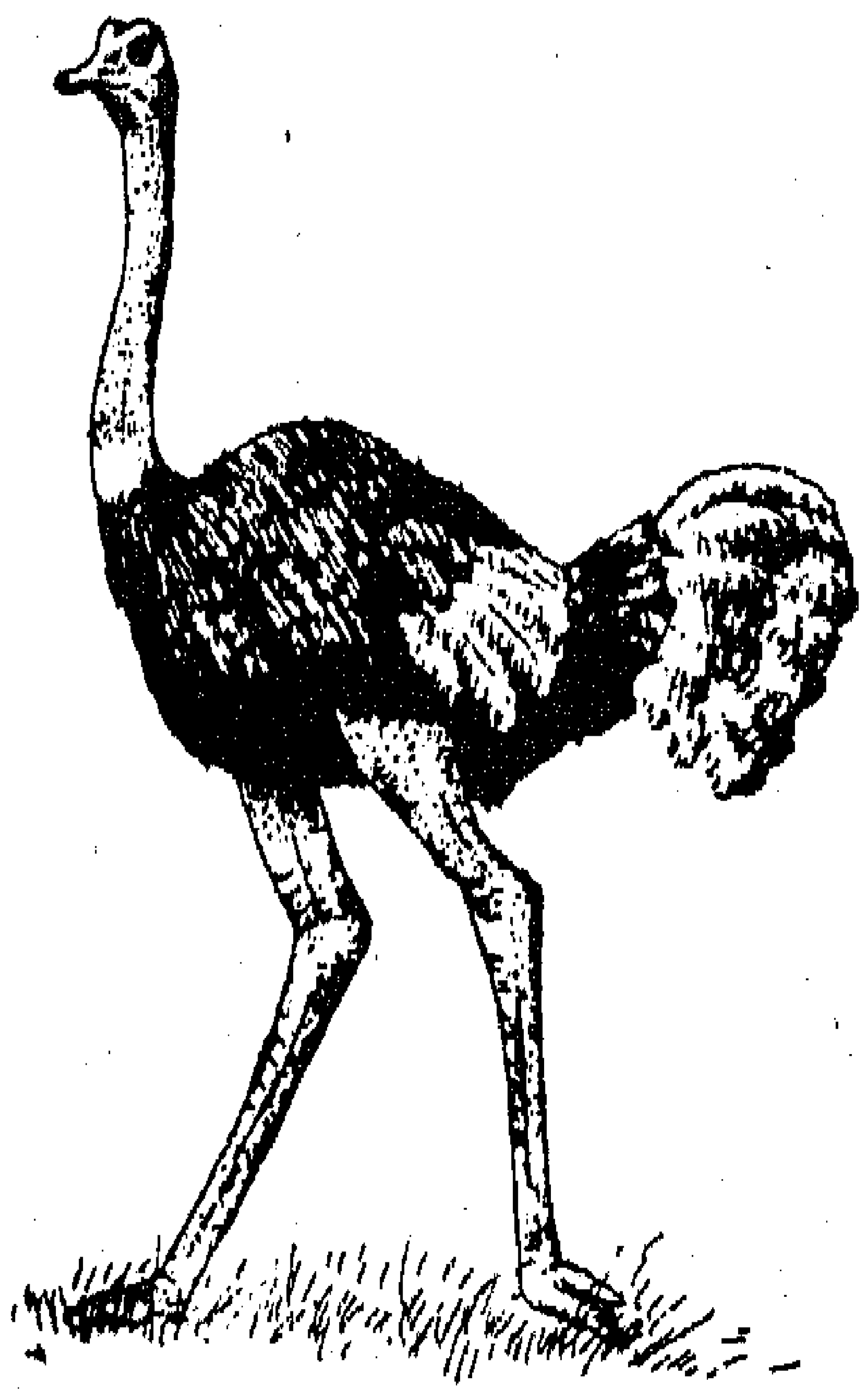


Fig. 80. *Ostrich*

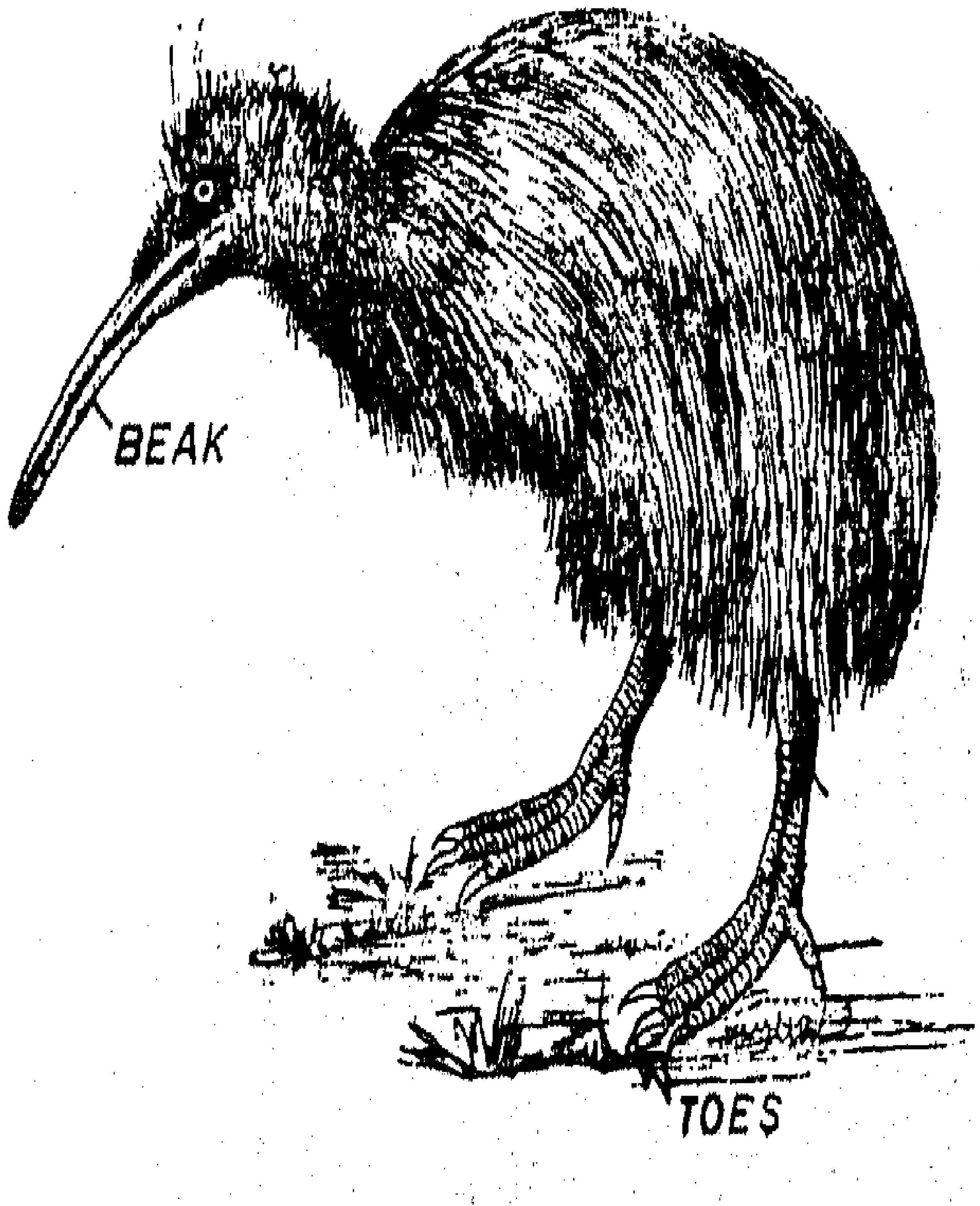


Fig. 81. *Kiwi*

Most of the birds can fly, but some are incapable of flight, though they can run fast. Thus the birds can be grouped as running birds or flightless birds (*Ratitae*) and flying birds (Carinatae); *e.g.*, Ostrich, Kiwi, Pigeon, Duck, Parrot, Kite, Owl, Sparrow Kingfisher.

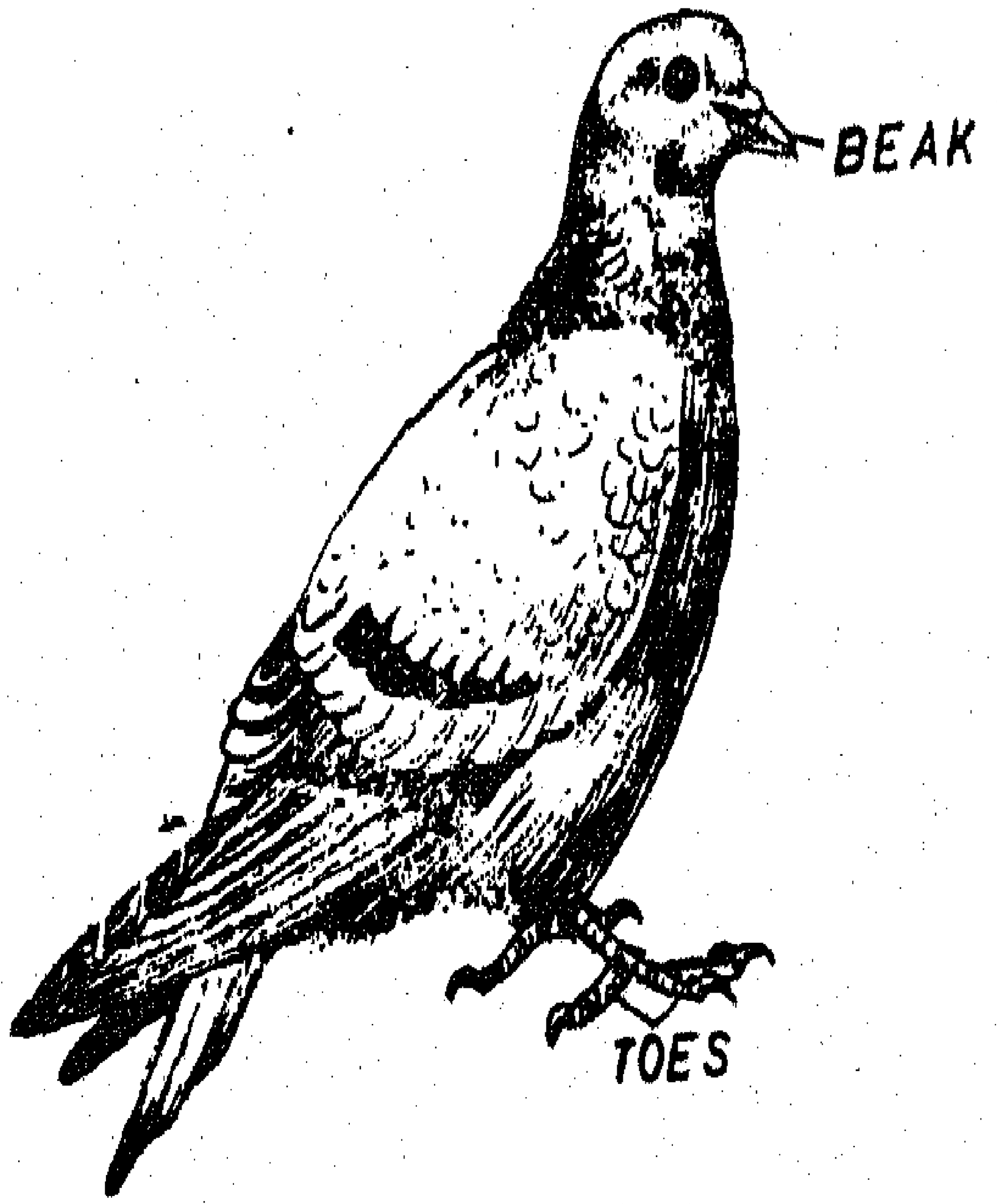


Fig. 82. *Pigeon*

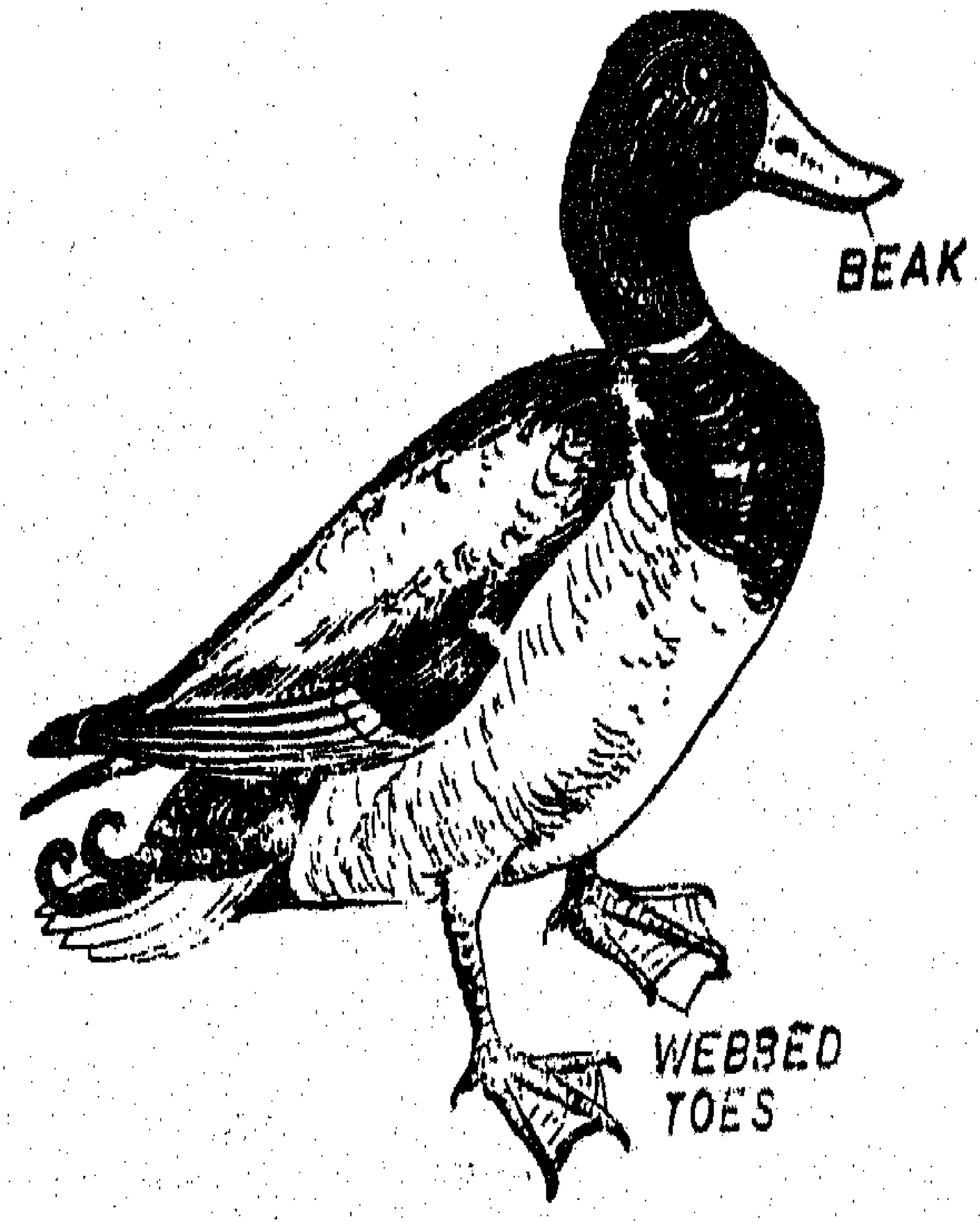


Fig. 83. *Duck*

Ostrich and Kiwi. (Figs. 80 and 81). These are flightless birds. Their wings are rudimentary, but their legs are well developed for running. The keel is absent.

Pigeons. They are common birds which are usually domesticated. (Fig. 82). They are mostly grain-eating birds and are good fliers.

Ducks. (Fig. 83). These are aquatic birds with a flattened bill used for feeding in shallow waters as well as on the ground. The toes of their feet are webbed. used for swimming and wading through water.

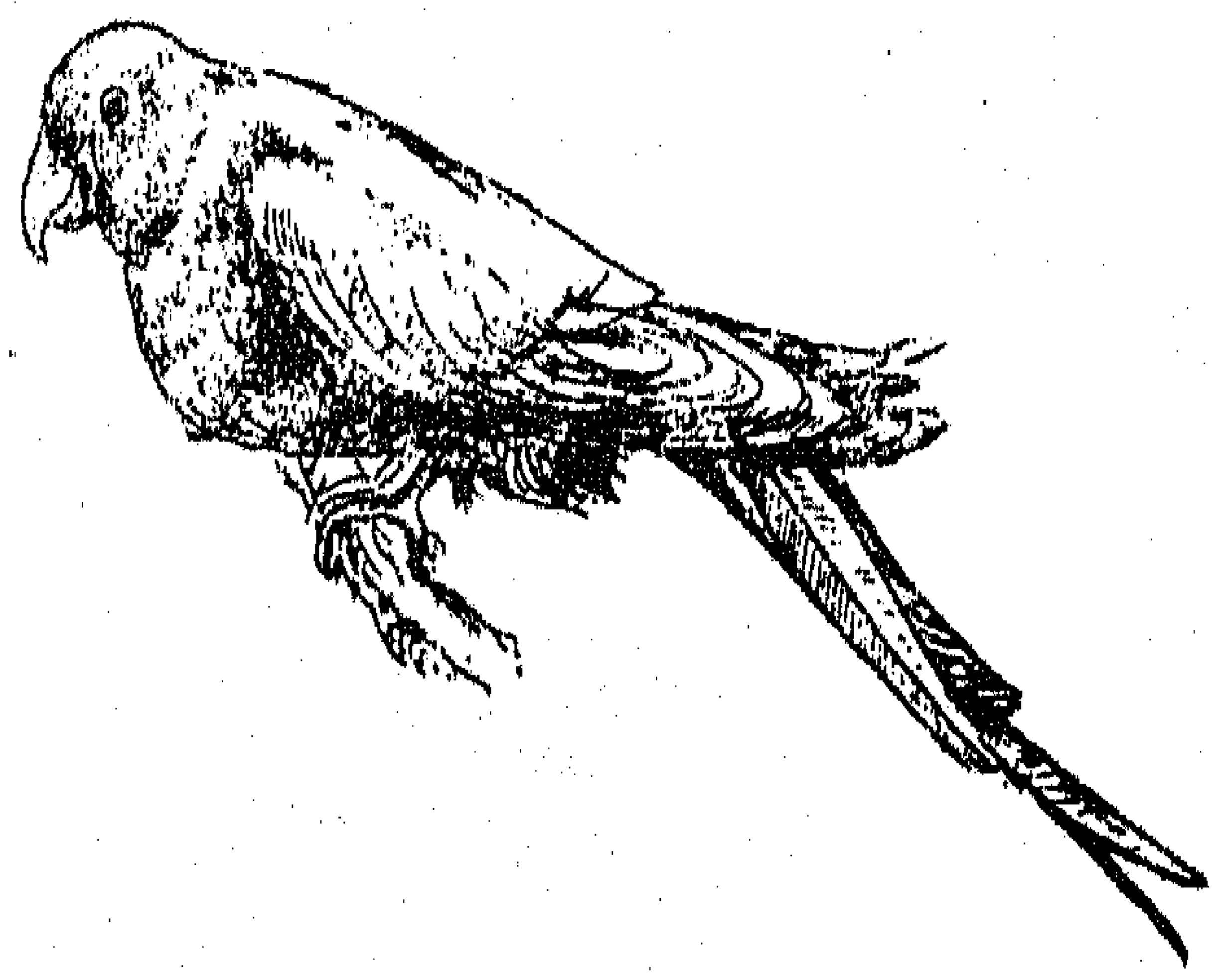


Fig. 84. *Parrot*

Parrots. (Fig. 84). They are usually kept as pets. They feed on fruits and nuts. Their beak is so modified as to help in cracking the nuts. The upper beak is curved. Their feet are with toes, having claws which are used for perching on trees.

Kites. (Fig. 85). These are birds of prey. They hunt by day. They have sharp, strong curved bill and powerful feet and bent claws. The make nests on tree-tops or grounds. The toes, with their claws, are used for grasping the prey, and the beak is used for tearing their flesh.

Owls. (Fig. 86). They resemble in some respects the kites and hawks in the structure of their beak and claws, for they are also birds of prey. They hunt by night.

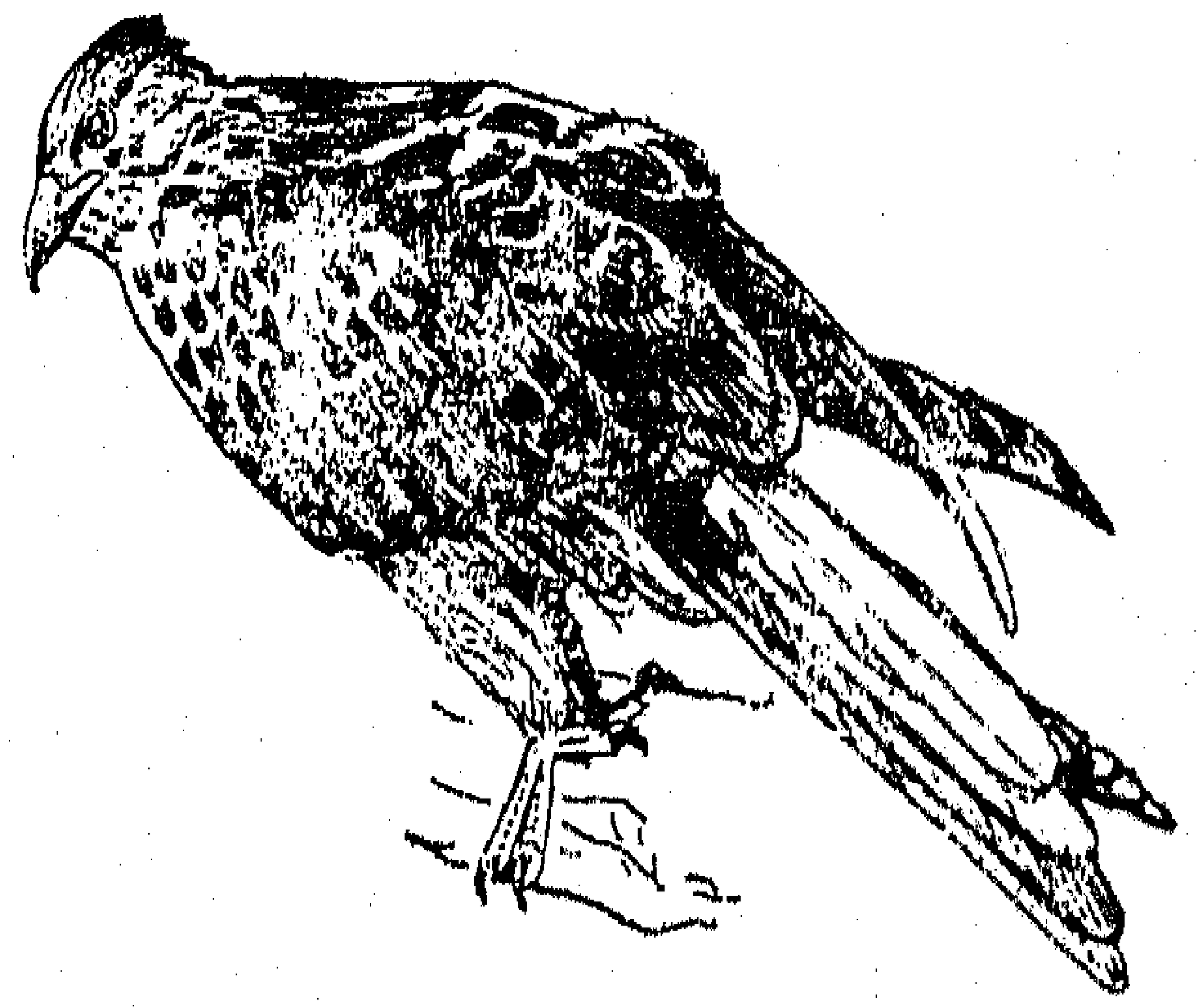


Fig. 85. *Kite*

Fig. 86. *Owl*

Class-Mammalia

The mammals form the highest group of animals in the animal kingdom. They are warm-blooded and terrestrial; a few have become secondarily aquatic, and some others have become aerial. They are usually covered with hair, the skin has many glands (sebaceous, sweat, and scent glands), including the mammary glands. The mammary glands in females secrete milk for nourishing the young ones. The ears have an external pinna. The eyes have movable eyelids. There are four limbs; each foot has 5 (or fewer) digits, which end in horny claws, nails or hoofs. The limbs are variously adapted for walking, running, climbing, swimming or flying. The teeth are in socket, and in most cases are of different types—the *incisors* for cutting, the *canines* for tearing, and the *molars* for grinding.

The heart is 4-chambered, with 2 auricles and 2 ventricles. The red blood corpuscles are non-nucleated usually circular (in camel R. B. C's are nucleated). There is no sinus venosus; only the left aortic arch present. Respiration is by lungs only. A muscular diaphragm between thorax and abdomen is present. The glottis is provided with epiglottis. The cerebral hemispheres are well-developed, reaching their maximum development in human beings. Corpus collosum, pons Varolii and corpora quadrigemina are present. The male has a copulatory organ—the penis.

The testes are commonly in a scrotal sac, external to the abdomen. Fertilisation is internal, and the development is inside the uterus of the female. The embryo is closely connected to the wall of the uterus by the *placenta.*

The mammals give birth to live young ones (*i.e.*, they are *viviparous*); *e.g.*, Rabbit, Rat, Squirrel, Shrew, Guinea pig, Bat.

Rabbits. (Fig. 87). They live in companies in under-ground burrows dug out by their front legs. They are herbivorous animals, eating a great variety of plants. They live for 7 to 8 years, and breed four times a year. They become sexually mature when they are 4 to 6 months old. Each litter may contain 5 to 8 young ones. The body consists of the following regions, the head, the neck, the trunk, and a tail. The entire body is covered with hair. The head bears a pair of long external ear pinnae. The eyes are with movable eyelids provided with eye-lashes. The nostrils are obliquely situated at the tip of the snout. The mouth is a transverse opening bounded by an upper and a lower lip. The upper lip is deeply cleft in the middle, through which the inner teeth, namely, the chisel-like incisors, can be seen. There are no canine teeth. The upper lip bears long hairs, forming the whiskers or *vibrissae.* The limbs are 4 in number. The hind limbs are long, used for jumping and have only four digits. The four limbs are short and have five digits. The digits end in claws. On the ventral surface of the body in the female, there are four to five pairs of papillae called *teats,* through which the ducts of the mammary glands open. At the base of the tail lies the anus. There is no cloaca. The anal and urino-genital openings are separate. In male the testes are enclosed in a scrotal sac.

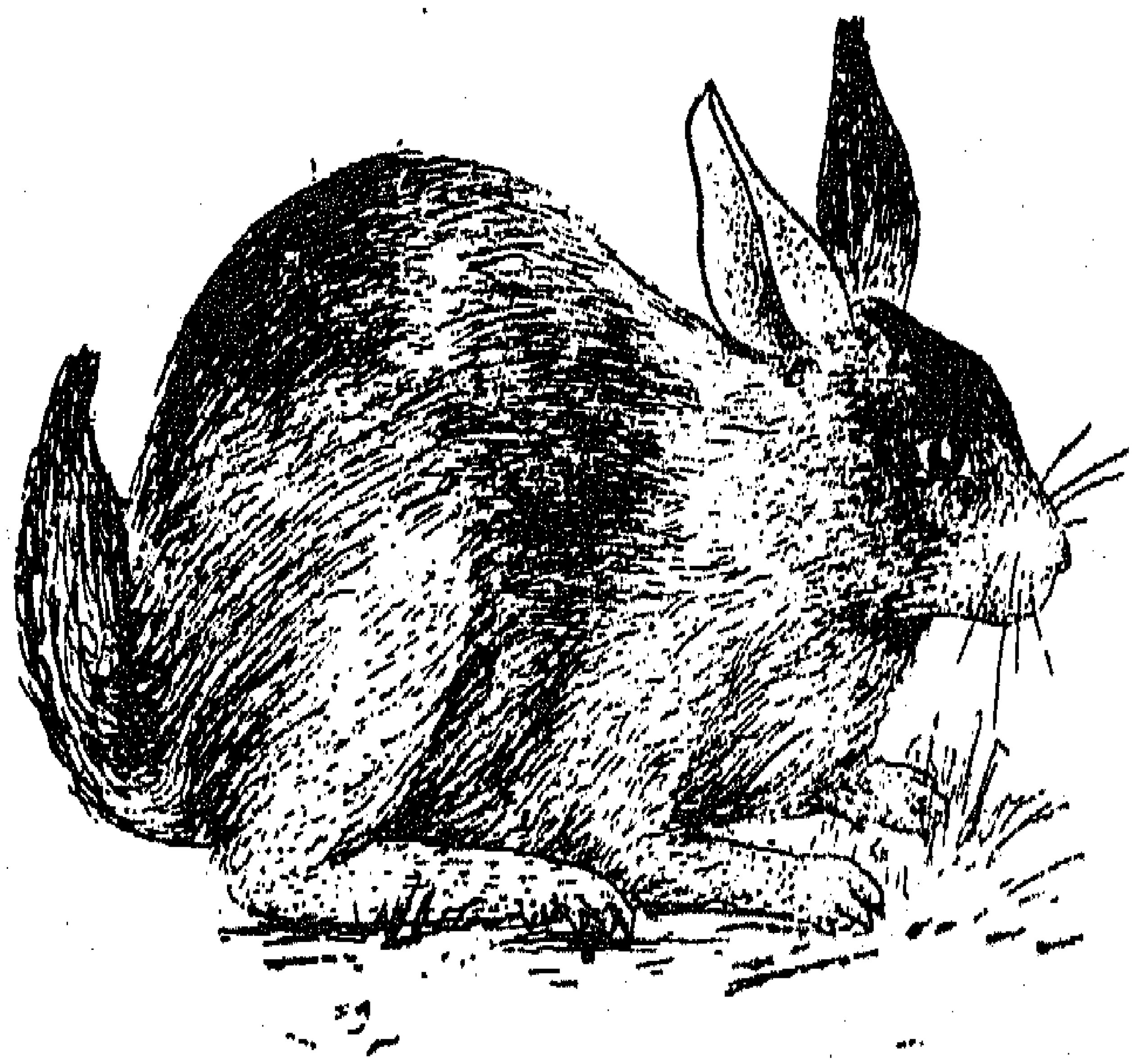


Fig. 87. *Rabbit*

Rats. (Fig. 88). They are gnawing mammals with a pair of incisors in each jaw with sharp cutting edges. The incisors are chisel-like and rootless, growing continuously. The head bears a pair of external ear pinnae. The eyes are covered with movable eyelids. There is a pair of nostrils. The mouth is bounded by lips. There are four limbs, each with five digits and ending in claws. The tail is long and slender.

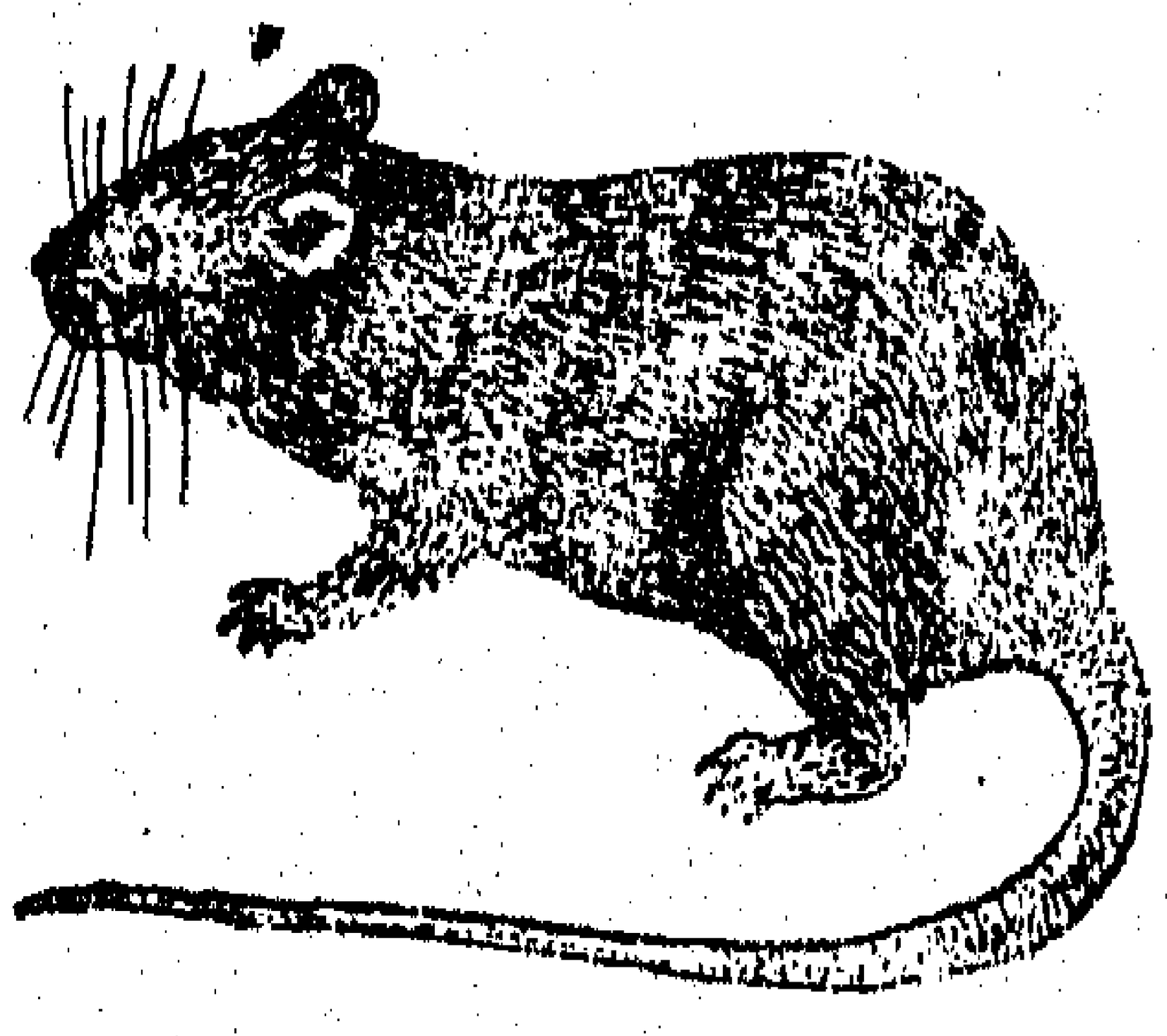


Fig. 88. *Rat*

Squirrels. (Fig. 89). They are found on the ground or on trees, running about from branch to branch. They feed chiefly on seeds and nuts. The head is fairly rounded with a pair of external ear pinnae, and a pair of eyes with eyelids. The snout is provided with vibrissae. The nostrils are at the tip of the snout. There are four limbs, with five digits in each limb, and provided with claws. The tail is bushy.

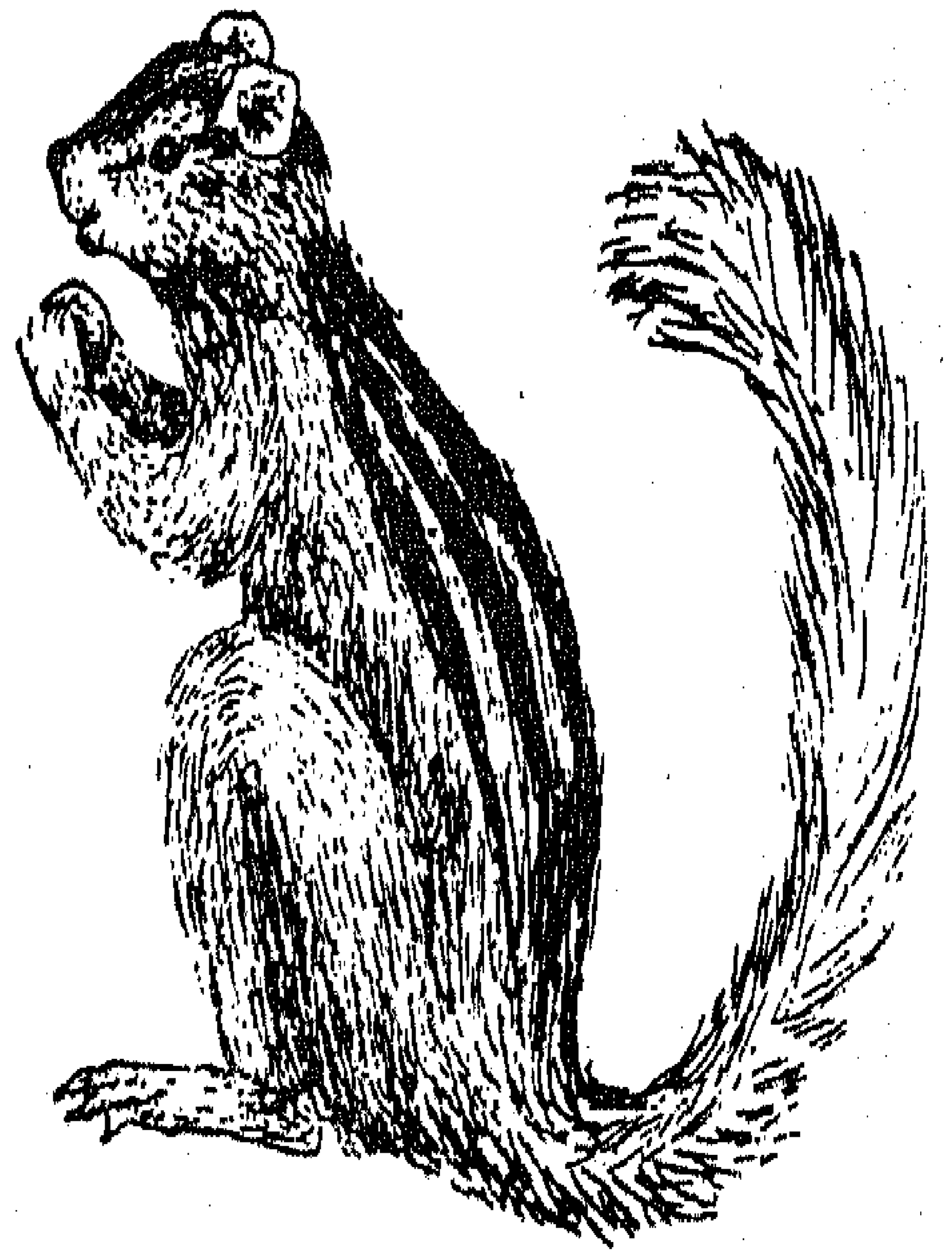


Fig. 89. *Squirrel*

Shrew. (Fig. 90). It is small in size and the snout is long and tapering. The foot has 5 digits, ending in claws. The teeth are sharp and pointed. Shrews feed on small insects and live in burrows, which they dig up by powerful clawed front legs.

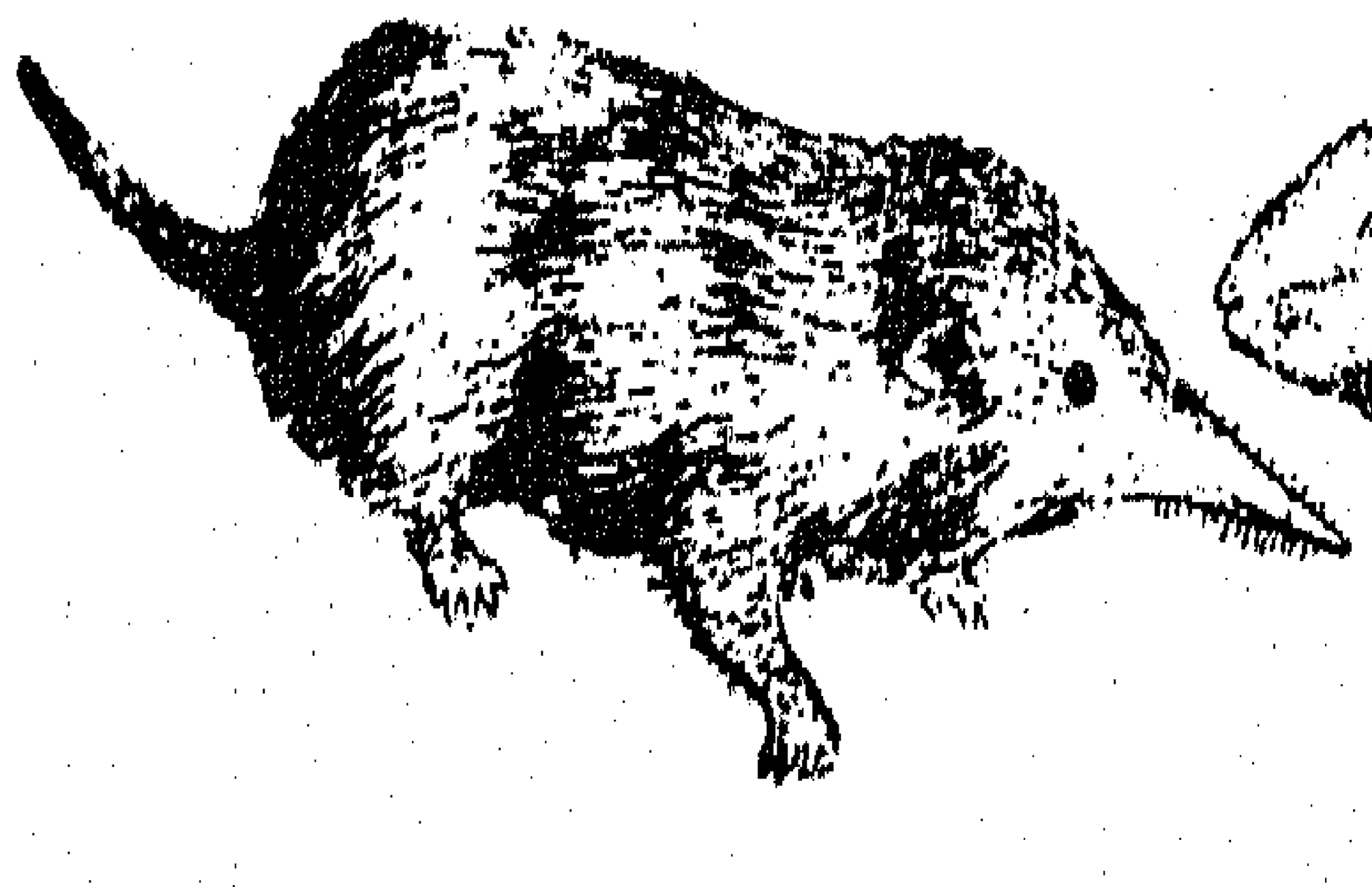


Fig. 90. *Shrew*

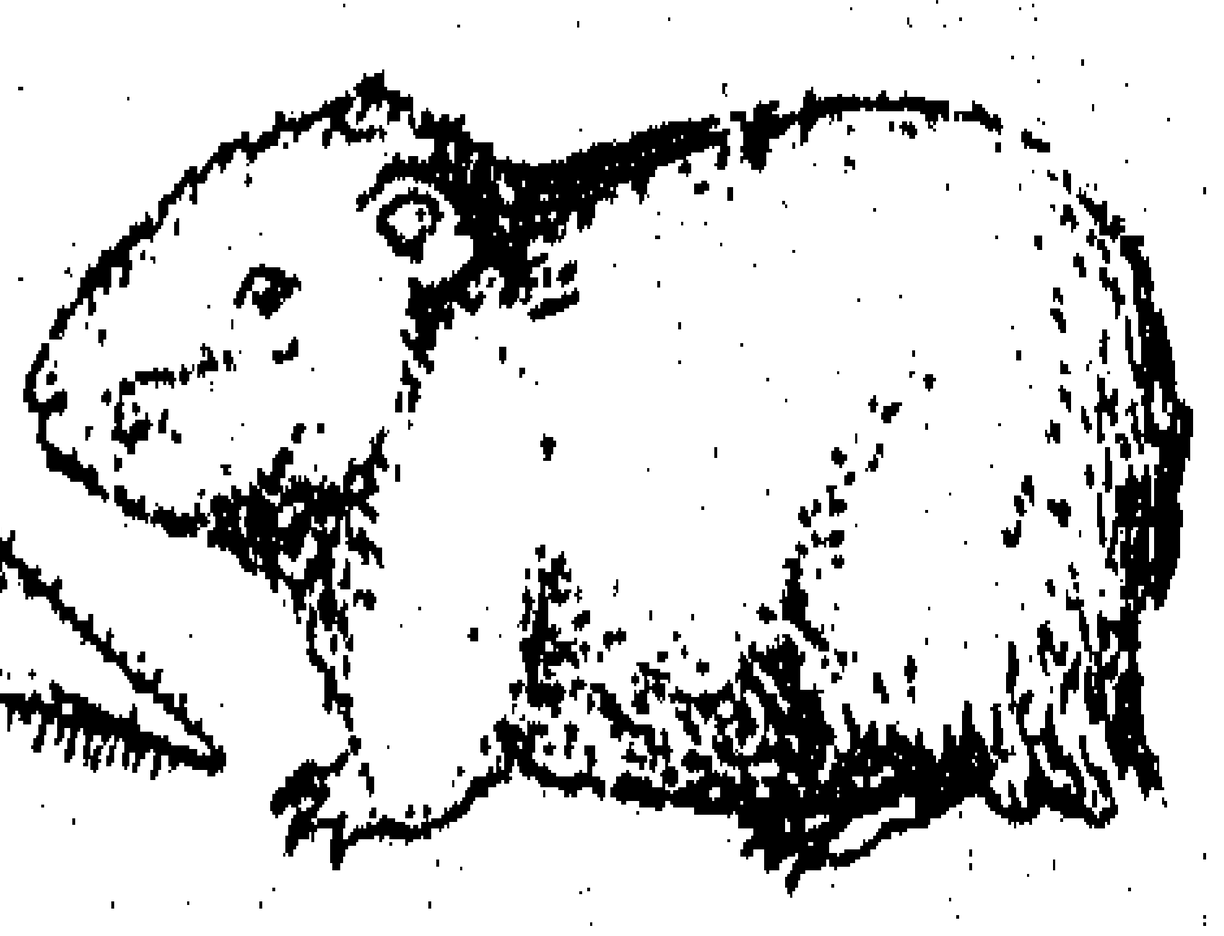


Fig. 91. *Guinea pig*

Guinea pigs. (Fig. 91). These small mammals are well known for the physiological and genetical experiments conducted on them. The head bears a pair of external ear pinnae and eyes. The snout is short, with vibrissae. There are 4 limbs with five digits each, ending in claws. They are herbivorous.

Bats. (Fig. 92). They are nocturnal mammals, the only flying mammals. The flight is performed with the help of the *patagium*, which is the lateral extension of the skin, stretching between the forelimbs and the hind limbs. The second to fifth fingers are greatly elongated to support the patagium. They sleep by day on tree branches, hanging head downwards with wings folded. They fly actively at night in search of food. They fly at high speeds, being equipped with a "radar" system, they can avoid obstructions coming in the way of their flight. Some live on insects and others on fruits.

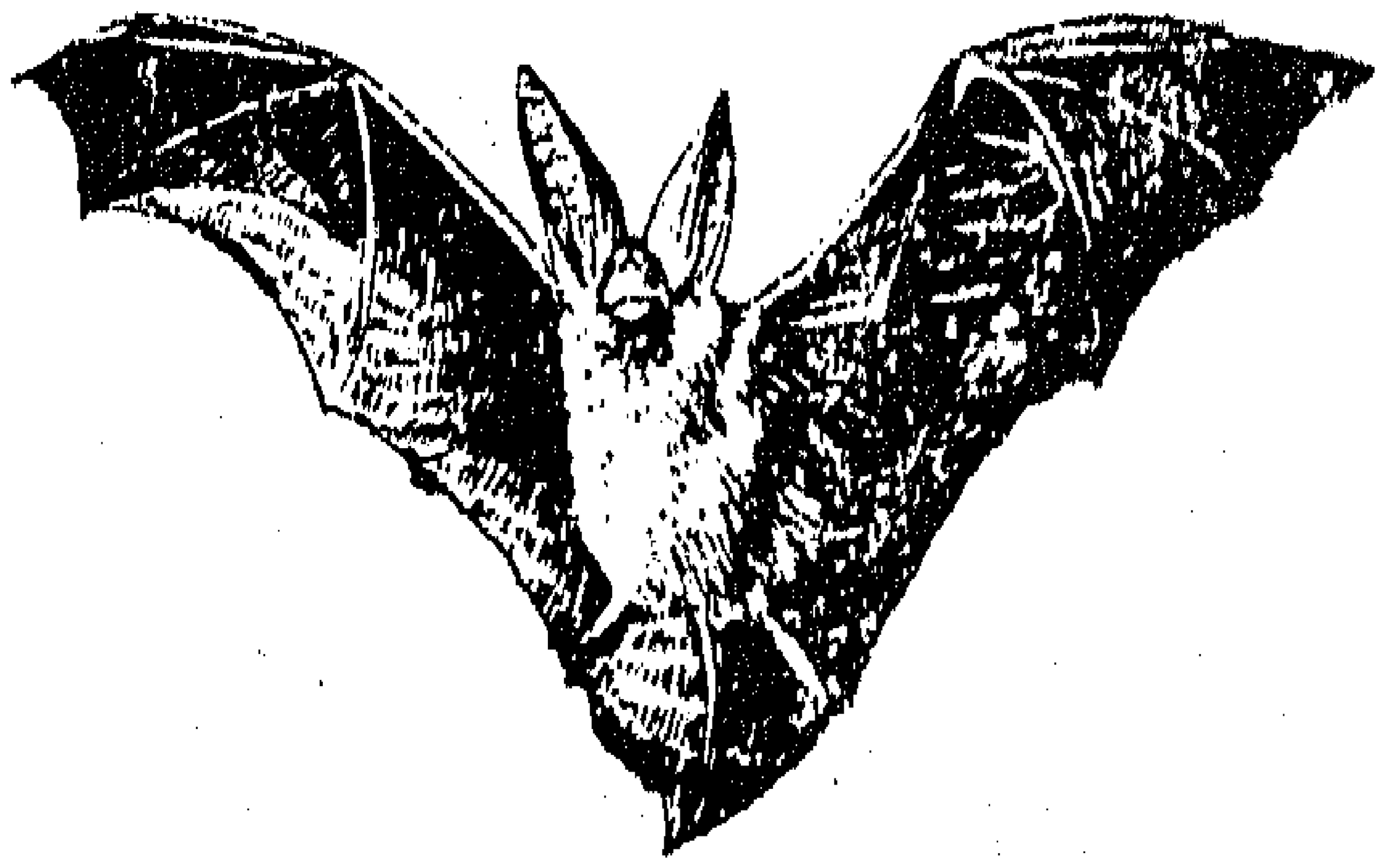


Fig. 92. *Bat*

The American vampire bats have large canine teeth by which they puncture the blood vessels of horses and cattle, and occasionally of man, and laps up the oozing blood as food.

SUMMARY

1 Animal Kingdom is divided into two groups (i) Chordates and (ii) Non-Chordates.

2. Vertebrata is a sub-group of Chordata and includes animals with backbones.

3. Non-Chordata includes animals without backbones.

4. Protozoa includes organisms which are acellular while metazoa includes multicellular animals.

5. Porifera includes animals with pores as in the sponges.

6. Coelenterata name comes from Greek word Kilos—hollow and enteron meaning gut. The animals have a single cavity the gastrovascular cavity as in hydra.

7. Platyhelminthes includes flat worms which may be free living or parasitic. These animals have no anus and they are hermaphrodite.

8. Nemathelminthes are round worms which differ from platyhelminthes in having a complete digestive system. The animals are unisexual.

9. Annelida are true worms which have elongated body divided into metameric segments. They are hermaphrodite and possess a ganglionated nervous system. The phylum includes animals like earthworm and leech.

10 Arthropoda comprises the largest phylum in animal kingdom. It includes animals with jointed appendages (Arthon-joint; podusfoot). The phylum includes animals like crab, lobster, centipede, millipede, scorpion, spider etc.

11. Mollusca are soft bodied animals, usually having a shell. They have a muscular foot.

12. Echinoderms are animals showing radial symmetry. The body wall has plates of calcium carbonate with protruding spines. Star fish, Brittle Star, Sea urchin etc., are animals included in this phylum.

13. Vertebrata includes five subphylla like (a) Pisces (b) Amphibia (c) Reptilia (d) Aves, and (e) Mammalia.

14. Pisces include fishes both cartilaginous and bony.

15. Class Amphibia includes animals like frog and toad which can live on land and in water.

16. Reptiles are cold blooded animals having dry skin covered with scales or bony plates. They are lung breathers with imperfectly divided 4 chambered heart. Reptiles like wall lizard, garden lizard and snakes belong to this class.

17. Class Aves includes birds which are warm blooded animals. They have a streamlined body covered with feathers.

18. Mammals are the most highly evolved animals. They are warm blooded and the body is covered by hair. They all possess mammary glands. Rat, Squirrel, Guinea pig, Bat and human beings are included in this group.

BIOLOGICAL WORDS

- Chordata
- Vertebrata
- Protozoa
- Metazoa
- Coelenterata
- Gastrovascular cavity
- Platyhelminthes
- Nemathelminthes
- Arthropoda
- Mollusca
- Echinodermata
- Pisces
- Amphibia
- Reptilia
- Aves
- Mammals
- Contractile Vacuole
- Scolex
- Coelom
- Metamorphosis

QUESTIONS

1. Write short notes on:—
   (a) Binomial nomenclature, (b) Species, (c) Chordate Characters.
2. What are the Characters of the Vertebrata? Describe the characters with at least two examples of any three of the Vertebrate classes.
3. How do invertebrates differ from Vertebrates?
4. Give the characteristics with at least two examples of the following groups:—
   (i) Aves, (ii) Amphibia, (iii) Mollusca, (iv) Annelida, (v) Platyhelminthes.
5. Classify any four of the following animals giving reasons:—
   (i) Squirrel, (ii) Euglena, (iii) Liverfluke, (iv) King fisher, (v) Chameleon, (vi) Spider, (vii) Sea Urchin.
6. Distinguish between:—
   (i) Frog and Toad, (ii) Starfish and Brittle star, (iii) Centipede and Millipede, (iv) Insect and Spider, (v) Lobster and Crab, (vi) Bony fish and Shark, (vii) Planaria and Liver fluke, (viii) Bat and Bird, (ix) Hydra and Sea anemone, (x) Octopus and Sepia, (xi) Eel fish and Snake, (xii) Catfish and Dog fish, (xiii) Salamander and Wall lizard.
7. State the functions of the following.
   (a) Scolex of tape worm, (b) Proglottis of tape worm, (c) Suckers of liverfluke, (d) Tentacles in Hydra, (e) Pleopods of lobster, (f) Pincer of crab, (g) Pedipalp of scorpion, (h) Booklungs in spider and scorpion.

Nutrition

6

As long as the body is alive, it requires a constant supply of food materials to provide the necessary energy for its day-to-day activities, to make good the wear and tear of cells and add up to the protoplasm, the material necessary for growth. The energy required by the body is locked up in the form of potential energy in the complex food substances that we normally eat. All this energy is converted into chemical energy by the slow burning (oxidation) of these food substances in the cells of the body. This energy is used for the metabolic activities of life. The bulk of the food substances that are taken into the body include the proteins, carbohydrates and fats. Apart from these substances, the body needs water, various inorganic salts and special substances known as vitamins.

All the materials by the body, except oxygen, are taken in by way of the digestive system. This process, by which the food is taken in, digested and transformed into part and parcel of our own body, is known as *nutrition.*

The process of nutrition includes :

(1) Ingestion; (2) Digestion; (3) Absorption; (4) Distribution; (5) Assimilation; and (6) Egestion.

(1) *Ingestion* is the process by which the animal takes food into the digestive cavity.

(2) *Digestion* is a process in which the complex and non-diffusible food substances are broken up into their simplest molecules by the action of the digestive ferments called *enzymes,* and made diffusible, through the wall of the alimentary canal, into the blood

(3) **Absorption** is a process of diffusion by which the digested food substances pass from the digestive cavity, through the wall of the digestive tube, into the blood.

(4) **Distribution** is the transportation of the absorbed, digested food substances to the different parts and cells of the body.

(5) **Assimilation** is the utilisation or conversion of the digested food substances into the protoplasm of the cells and tissues, thus forming the most important phase in nutrition, which is also the ultimate aim of digestion.

(6) **Egestion** is the disposal of the undigested, unabsorbed residue of food from the digestive cavity.

The process of nutrition carried out in different animals is varied. Accordingly, there are four methods of nutrition :

(1) **Holozoic.** This type of nutrition takes place in animals in which the complex organic food is taken into the digestive cavity through the mouth for further digestion.

(2) **Holophytic.** It is a plant-like nutrition. The organic food material is synthesized out of the raw inorganic substances such as CO_2 and water. This is more prevalent in plants and is also seen to some extent in lower animals, like *Euglena.* This process, known as photosynthesis, is accomplished with the help of chlorophyll in the presence of sunlight.

(3) **Saprophytic.** This particular type of nutrition occurs in lower plants such as yeast, bacteria, mucor etc., which do not possess chlorophyll. They depend upon decaying organic food material for their sustenance.

(4) **Saprozoic.** In this type of nutrition, animals depend upon decaying organic substances.

(5) **Parasitic.** In this type of nutrition the organisms live at the cost of other organisms, which are called as a host.

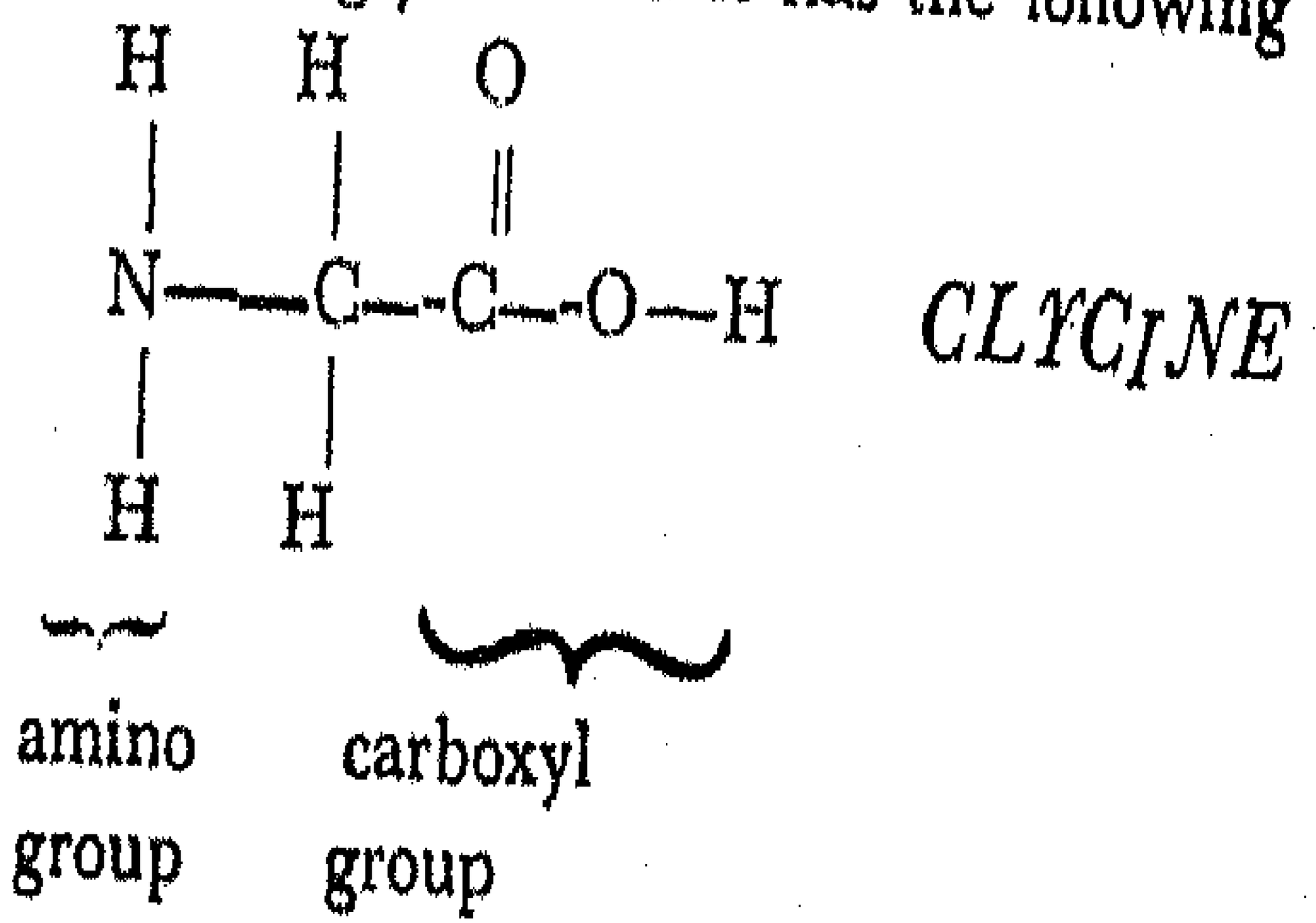
Food

Food is the main source of energy in its potential form. It is also the substance which builds up the body and helps in the repair of wear and tear. For proper growth and general health, animals require a complete and well-balanced diet, which includes the required organic as well as inorganic food substances.

The organic constituents of the food that we eat are mainly (1) Proteins; (2) Carbohydrates; (3) Fats; and (4) Vitamins.

The inorganic constituents are (1) Water and (2) Salts.

Proteins. The proteins are complex organic compounds containing nitrogen in addition to carbon, hydrogen and oxygen, and hence they are called "nitrogenous compounds". In addition, the protein may contain sulphur and, in certain cases phosphorus. Amino acid is the structural unit of any protein. When a number of amino-acid molecules get linked together, they form complex protein. Thus the building stones or units of protein are amino-acids. Amino-acids are characterised by having a carbon atom to which one amino group and one carboxyl group are attached. The simplest amino-acid is glycine and it has the following formula :

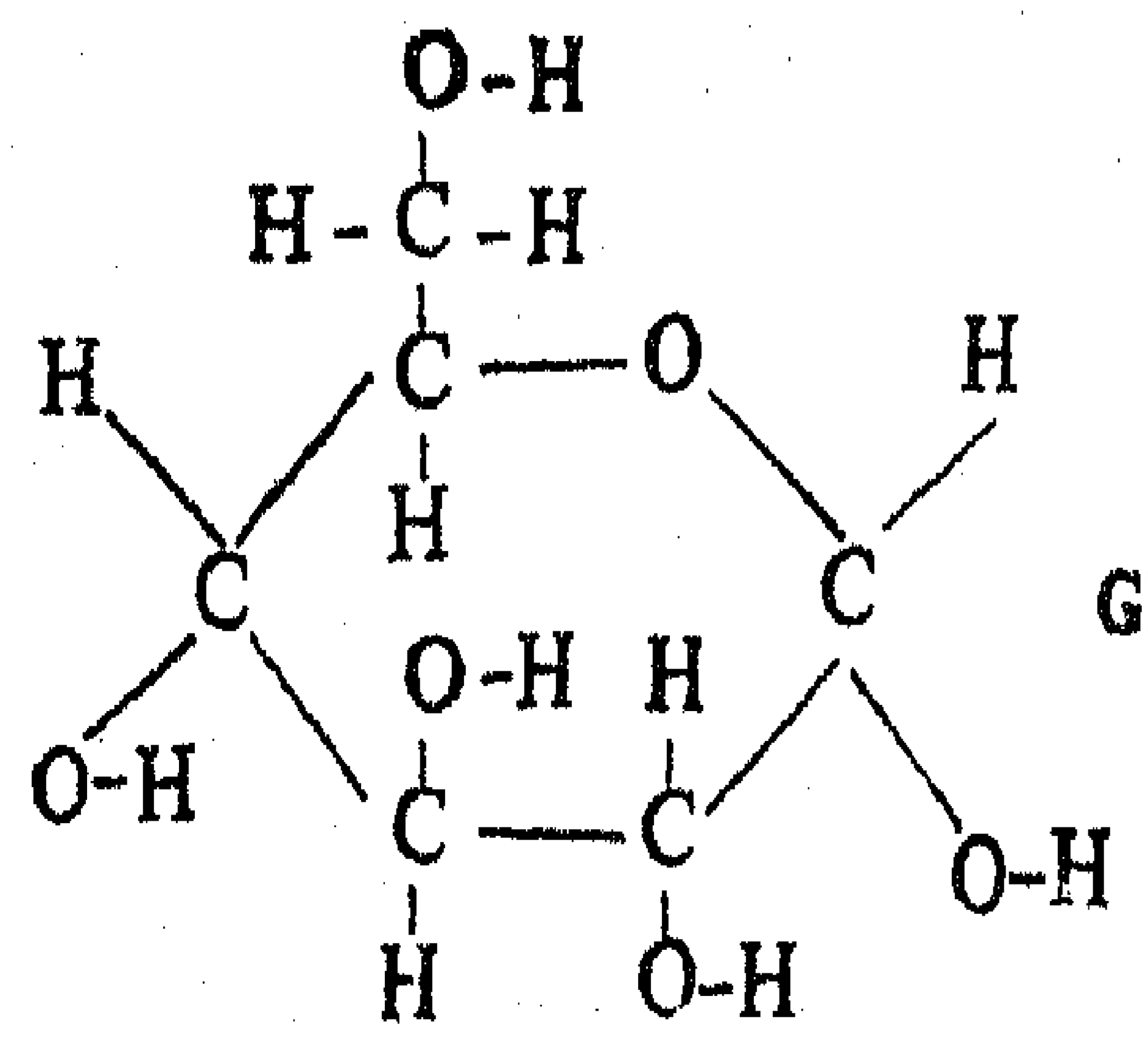


Protein. molecules are of the complex type and they cannot pass through the cell membrane. It is only when they get split up into their simplest amino-acid molecules that they become available to the cells. All organisms require protein for their growth and repair, but protein may also be used as fuel to release the energy for day-to-day activities. Unlike plants, animals depend on other organisms for their protein requirements.

The common sources of protein are meat, fish, eggs, milk, peas, beans, etc.

Carbohydrates. The carbohydrates contain carbon, hydrogen and oxygen. The hydrogen and the oxygen are in the same proportion as in water. There are three main types of carbohydrates of biological importance : simple sugars, double sugars, and complex sugars.

The simple sugars are called *Monosaccharides.* Glucose, galactose and fructose are the monosaccharides and all have the formula — $C_6 H_{12} O_6$. The structural formula is show on page 82.



GLUCOSE

The double sugars or the *Disaccharides* are formed when two molecules of monosaccharides unite, with the loss of one molecule of water. The formula for a double sugar is $C_{12}H_{22}O_{11}$, *i.e.*, $C_6H_{12}O_6 + C_6H_{12}O_6 = C_{12}H_{22}O_{11} + H_2O$.

The three important double sugars are *sucrose* (cane sugar), *lactose* (milk sugar) and *maltose*. Sucrose is formed by the combination of one molecule of glucose and one molecule of fructose. One molecule of glucose and one molecule of galactose go to form the lactose; while maltose is formed by two glucose molecules. Maltose is of interest since it appears as an intermediate form during the digestion of starch.

The complex sugars or the *Polysaccharides* are formed by the combination of many molecules of simple sugars, with the loss of an equal number of water molecules. The formula is $n(C_6H_{10}O_5)$ *i.e.*,

$$n(C_6H_{12}O_6)—n(H_2O)=n(C_6H_{10}O_5)+n(H_2O).$$

Starch, *glycogen* and *cellulose* are the most abundant types of complex sugars.

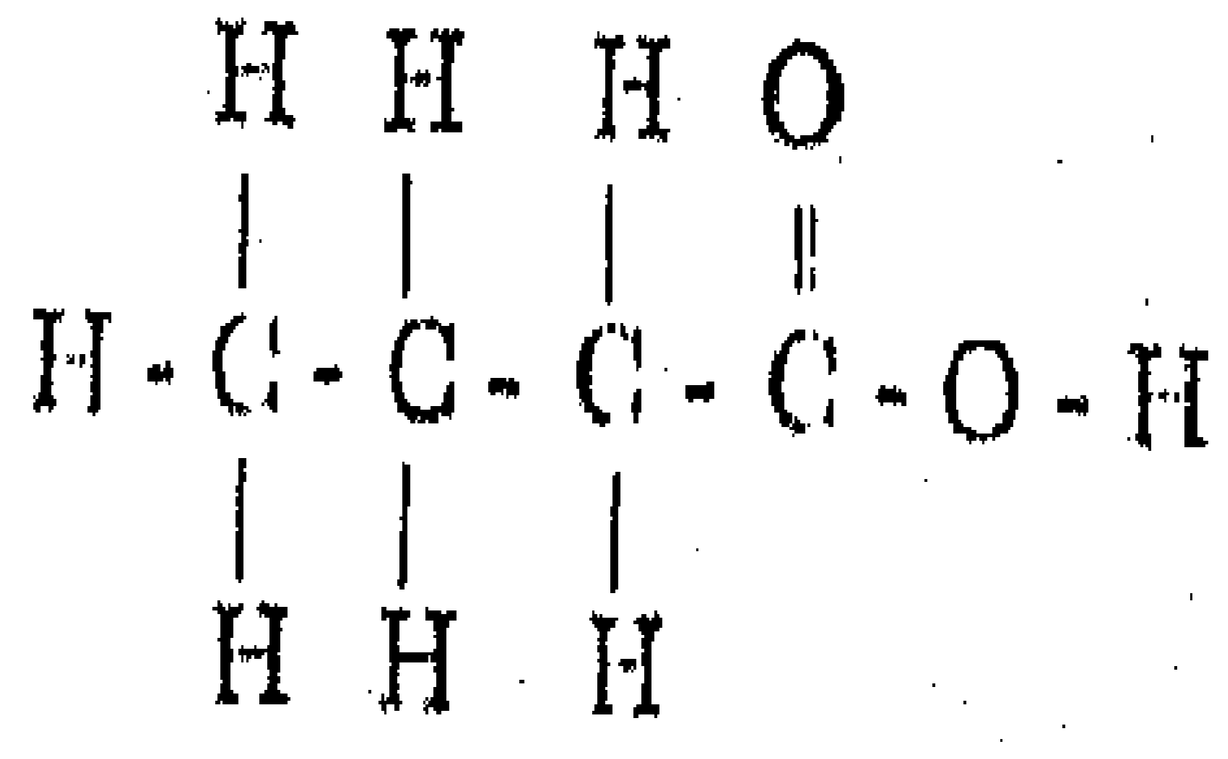
Starch is found in cereals like wheat, maize and also in potatoes, banana, etc.

Cellulose is an important component of the cell walls of plants.

Glycogen (or animal starch) is the most abundant complex sugar in the animal body, and it is also found in some plants. In man, it occurs primarily in the liver and muscle cells. It is formed by polymerisation of glucose in the liver.

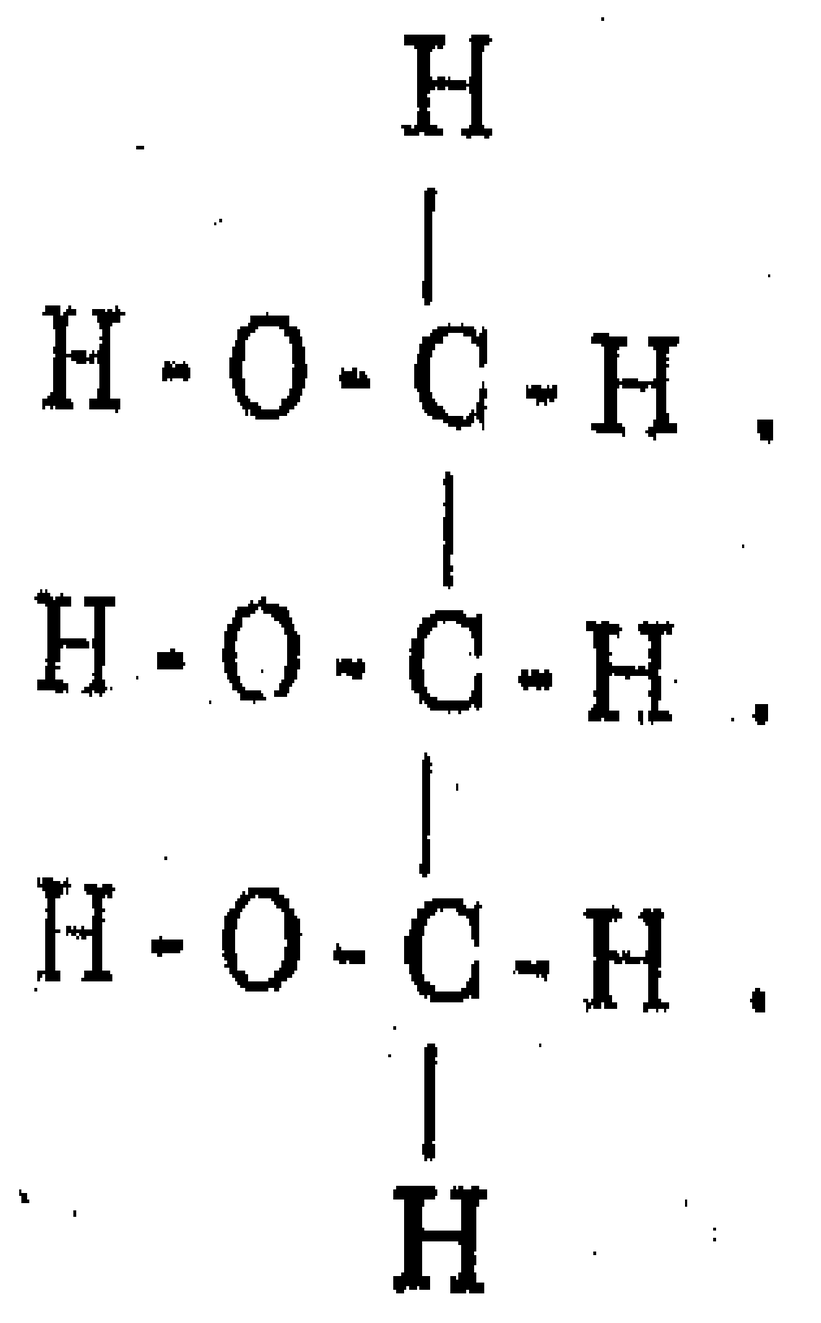
Carbohydrates serve as a source of chemical energy. They are, therefore, energy foods or fuel foods, since their oxidation releases the required energy.

Fats. Like carbohydrates, the true fats are made up exclusively of oxygen, carbon and hydrogen. The amount of oxygen content is comparatively less than that which is present in the carbohydrates. As in the case of carbohydrates, oxidation of fats results in the release of energy and the production of carbon dioxide and water. However, more oxygen is required to oxidize a fat than is necessary to oxidize a carbohydrate, and thus the energy derived from fat is correspondingly greater. Therefore, the fats are concentrated energy foods, their caloric value being more than double that of carbohydrates. Each molecule of fat is formed by the combination of a molecule of glycerol (glycerine) with three molecules of fatty acids. The structural formula of glycerol and fatty acids is as follows:



$$H-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{H}{C}}-\overset{O}{\overset{\|}{C}}-O-H$$

Butyric Acid



$$\begin{array}{c} H \\ | \\ H-O-C-H \\ | \\ H-O-C-H \\ | \\ H-O-C-H \\ | \\ H \end{array}$$

Glycerol

The complete absorption of fats by the wall of the intestine requires that they should be broken down into fatty acids and glycerol.

The sources of fat are ghee, butter, cream, oils, nuts, fish, etc.

Water. Since the protoplasm contains a good deal of water, water forms an essential item in the nutrition of all organisms. It forms about 60% to 80% of our body weight.

(i) Water is the best medium in which the organic and inorganic substances get dissolved. The importance of water as a solvent will be appreciated when it is realised that chemical reactions are greatly speeded if the reacting substances are dissolved.

(ii) Water promotes the ionization of compounds. If substances are in the ionic form, they react more readily than when they are compounds.

(iii) Water is the medium of transport of useful materials like food, hormones, etc. in the body, and in the removal of waste matter from the different parts of the body.

(iv) Water helps in the regulation of body temperature.

Thus water alone has the necessary combination of physical and chemical characteristics to serve as a basis for protoplasmic activity. Daily loss of water from the body, by way of respiration, perspiration and urine, is made good by the drinking of water directly. Some water is also obtained by way of food.

Salts. All animals require certain salts in their diet. If the salts are not present in sufficient quantities, the normal bodily functions (metabolism) receive a setback. We need these salts in very small quantities.

The important salts required by the body include chlorides, sulphates and phosphates of calcium, sodium, potassium, iron, magnesium and zinc. Minute quantities of iodine, copper, manganese, cobalt and bromine are also needed.

Salts regulate the proper functioning of nerves, muscles and heart. Calcium is essential for the healthy development of teeth and also for the clotting of blood. Iron is necessary for the formation of the haemoglobin of the blood. Deficiency of iodine results in the enlargement of the thyroid gland, and results in a disease known as *goitre*.

The sources of salts are water, fruits and green vegetables.

Vitamins

Apart from proteins, carbohydrates and fats, vitamins are the other important substances which are absolutely essential for the normal growth and proper functioning of the body. They can be absorbed without digestion, and only very small amounts are needed for normal nutrition. They are the products of the plant world, from where they are obtained by animals.

They are found in food, preformed or as "provitamins" which are converted into vitamins; *e.g.*, carotenes are transformed into vitamin A. Some vitamins are produced by bacteria in the digestive tract; *e.g.*, Vitamin K, but not in sufficient amounts.

The necessity of vitamins in diet is felt in the manifestations of certain deficiency diseases caused by their absence or deficiency. Their total absence from the diet may eventually lead the animal to its death. The effect of the complete lack of a vitamin is known as "avitaminosis" and that of insufficient amount as "hypovitaminosis."

The term *vitamin* was suggested in 1912 by Funk. The chemical composition and structure of the vitamins was not known for a long time, and hence they were designated by alphabetical letters—A, B, C, D, E, etc. Today, however, the chemical nature and the physiological action of many vitamins are known, and appropriate chemical names have come into use. Some of them have been isolated in pure state, and are also prepared in the laboratory by synthesis.

Vitamins are divided into two groups: (1) Fat soluble and (2) Water soluble. The first group includes vitamins A, D, E; and the second group has vitamins of the B complex group (B_1, B_2, etc.) C, etc.

Vitamin A. This is a fat soluble vitamin.

Sources. It is found in liver, kidney, egg yolk, milk, butter, cream, cabbage and certain green and yellow vegetables like carrot, tomatoes. Vitamin A is found as a yellow pigment called "carotene", which is most abundant in carrots and is converted into Vitamin A, after it has been taken into the animal body. Cod liver oil and shark liver oil contain large quantities of Vitamin A.

Vitamin A is called the vitamin of growth. It is necessary for the proper growth and maintenance of normal epithelial tissue, for promoting the normal growth of bone and tooth enamel. Lack of this vitamin in food hinders the normal growth of the young animal and causes *"night blindness"*, (*i.e. Nyctalopia*) inability to see under twilight conditions. The skin becomes dry and scaly. In vitamin A deficiency wounds heal very slowly.

Vitamin B. This vitamin is available in the form of B$_1$, B$_2$, B$_6$, B$_{12}$, folic acid, etc., and thus is called as B-complex.

Vitamin B$_1$ (Thaiamin): This is water soluble.

Sources. It is found in yeast, nuts, pork, whole grains like wheat and rice, egg-yolk, peas, liver, milk, green vegetables, tomatoes, etc. It is present in the outer coating of seeds. Therefore, it is absent in polished rice.

It is quite necessary in the metabolism of carbohydrates in all the cells of the body. Deficiency of this vitamin causes beri-beri—a nervous disease which results in extreme weakness and nervous symptoms like neuritis, loss of appetite, circulatory disturbances, malfunctioning of heart, poor sleep, etc. Beri-beri is widespread where people depend exclusively on rice, especially on polished rice—in Japan, China, Malaya and India (particularly in the south).

Vitamin B$_2$ (Riboflavin): This is water soluble.

Sources: It is found in yeast, milk, liver, eggs, cheese, green vegetables, meat, kidney and fish.

On account of its wide occurrence, the diseases caused by a lack of it are not common. This vitamin plays an important role in oxidation reactions associated with cell respiration and in carbohydrate and protein metabolism. Deficiency of this vitamin is manifested in the cracking and reddening of the lips, fissuring at the angles of the mouth, inflammation of the tongue, which becomes bright red or magenta in colour. It also causes eye disorders, particularly itching, burning of the eye-ball and sometimes invasion of the cornea by blood vessels.

A disease called *Pellagra* is caused in man by the deficiency of the so-called pellagra-preventing (P.P.) factor or anti-pellagra vitamin. In this disease, blisters appear on the skin, and the tongue swells with the formation of ulcers.

Vitamin C (Ascorbic acid): It is also water soluble.

Sources: It is found in citrus fruits (*e.g.*, lemon, orange, sweet lime, grape fruit, etc.), tomatoes, potatoes, green leafy vegetables and cabbage. It can be synthesised by many animals except man, monkey and guinea pig.

This vitamin affects the health of the tissues. It is necessary for the formation of intercellular substances in the cartilage and bone. This vitamin is also necessary for normal tooth formation and for the maintenance of healthy gums. Its deficiency causes a disease known as *Scurvy*, the symptoms of which are redness, swelling and bleeding of the gums and ultimate decay and loss of teeth. The capillary walls are weakened, and bleeding occurs (haemorrhage) in the skin, mucous membranes, bones, joints and muscles. Wounds are slow to heal.

Vitamin D: It is a fat soluble vitamin.

Sources: Only a few foods in the average diet contain vitamin D: *e.g.*, egg-yolk, fish, liver oils (cod and shark), butter, milk, etc. Vitamin D is also synthesised in the body by the exposure of the skin to the ultra-violet rays in sunlight.

In the absence of a sufficient amount of vitamin D in the body, calcium and phosphorus cannot be absorbed properly from food and retained in the body. A deficiency of this vitamin results in a lack of calcium and phosphates, producing in children the disease known as *rickets* and *osteomalacia* in adults, in which the bones become soft, bent and deformed.

A prolonged intake or overdose of vitamin D is injurious and may cause even death because of the rise of calcium and phosphates which cause calcification of such organs as kidneys, lungs or heart.

Vitamin E. It is a fat soluble vitamin.

Sources It is found in vegetable oils, seeds, germinating wheat, cabbage, alfalfa, lettuce, unpolished rice, milk and egg yolk.

This vitamin is necessary for normal reproduction. Experiments on rats have shown that its deficiency causes sterility. In the male, there is degeneration of the testes, and in the female its deficiency causes the death of the embryo. This vitamin is also called anti-sterility vitamin. It is indispensable in several animal species, but there it no evidence that it is necessary for man.

Vitamin K. This vitamin is also fat soluble. It occurs in 2 forms—K$_1$ and K$_2$.

Sources: K$_1$ is present in pork, liver, green vegetables, tomatoes and egg-yolk. K$_2$ is synthesised by intestinal bacteria.

Vitamin K acts upon the liver so as to produce *prothrombin*, a substance essential for the clotting of the blood. The basic function of this vitamin is to prevent haemorrhage.

Vitamin K deficiency is rare, for intestinal bacteria synthesise this vitamin. Its deficiency leads to excessive bleeding, since it prolongs coagulation.

SUMMARY

1. Nutrition includes five processes, namely, (a) Ingestion (b) Digestion (c) Absorption (d) Assimilation and (e) Egestion.
2. Food contains carbohydrates, proteins, fats and Vitamins.
3. The simple products of carbohydrates are glucose, that of protein, aminoacids and of fat, glycerol and fatty acids.
4. Vitamins are necessary to keep the body healthy.
5. The deficiency of vitamins cause various diseases as follows:
    1. Vit. A—Night blindness
    2. " B—Complex-Beriberi, inflammation of tongue, pellagra etc.
    3. " C—Scurvy
    4. " D—Rickets and Osteomalacia
    5. " E—Sterility
    6. " K--bleeding in the absence of coagulation blood.

BIOLOGICAL WORDS

Nutrition
Ingestion
Egestion
Digestion
Assimilation
Carbohydrate
Protein

Vitamin
Beri-beri
Sterility
Rickets
Pellagra
Scurvy
Coagulation

QUESTIONS

1. Explain the term 'Nutrition'.
2. Describe briefly the various constituents of food.
3. Write notes on:
    (a) Vitamins, (b) Proteins, (c) Importance of water.
4. Give one important use of the following:—
    (i) Vitamin A. (ii) Carbohydrates, (iii) Calcium (iv) Fats, (v) Vitamin C(vi) Vitamin E
5. Fill in the blanks:
    (a) Beriberi is caused due to the deficiency of the Vitamin——
    (b) Vitamin K deficiency causes——
    (c) Vitamins were first discovered by ——

Organs of Nutrition in Man 7

The digestive system consists of a digestive tract or alimentary canal and certain digestive glands associated with it. The alimentary canal is concerned with ingestion, digestion, absorption and ultimately the egestion of the undigested residue of food. The digestive glands assist in digesting the complex food substances into their simple forms.

Alimentary canal in man

The alimentary canal starts with the mouth. It it bounded by an upper and a lower lip, which are fleshy. The mouth leads into a space, the mouth cavity or *buccal cavity* (Fig. 13).

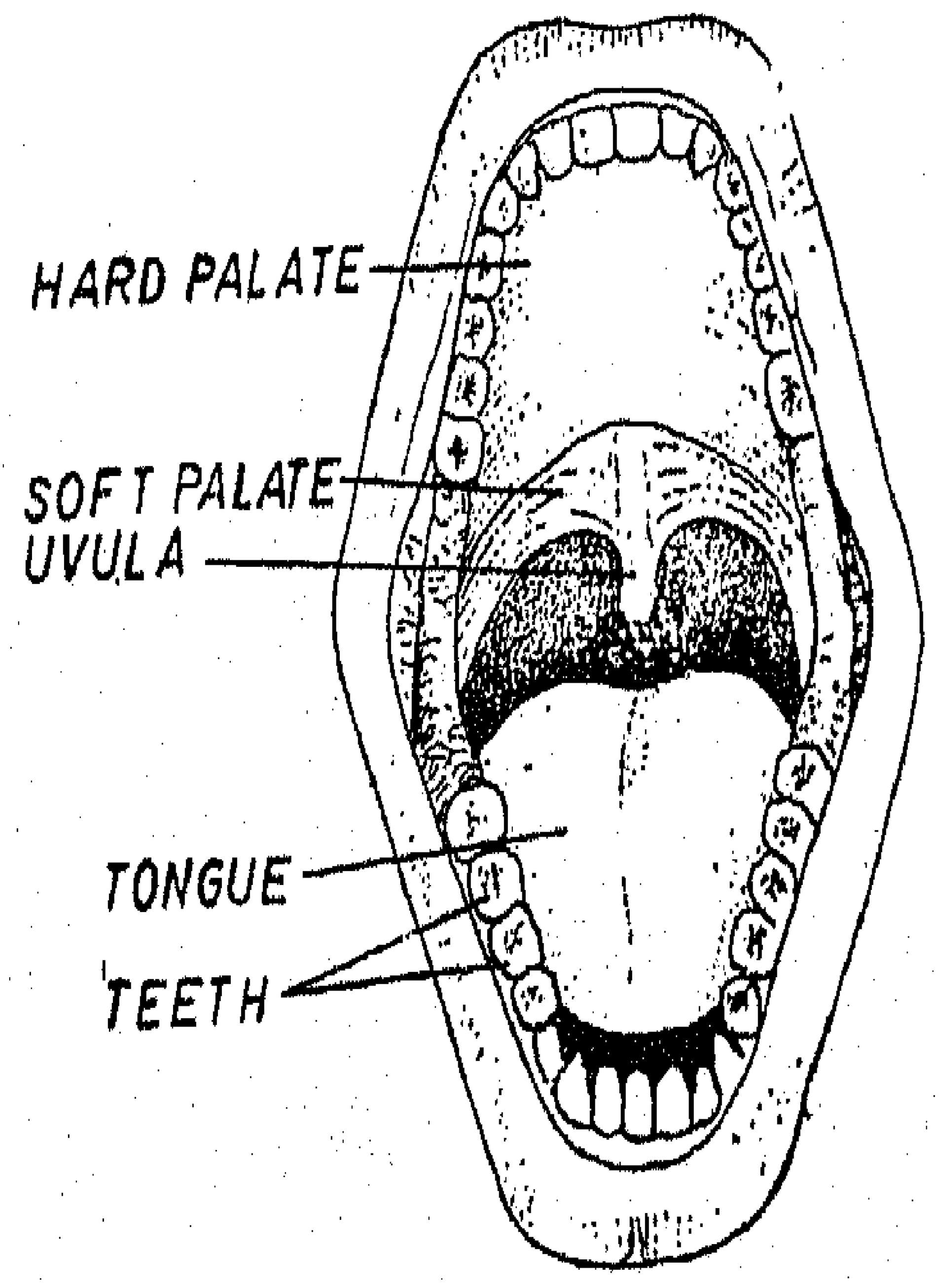


Fig. 93. *Buccal cavity.*

This cavity it bounded by an upper and a lower jaw. These bony jaws carry teeth of different kinds, which help in breaking

and crushing the food. The teeth grow in two successive sets. The first set consists of only 20 teeth, and they fall off by about the age of 7-8 years, when they give place to the 32 permanent teeth present in the adult. The first set is called *Milk dentition*, while the second set is known as *Permanent dentition*. Of the 32 permanent teeth, each jaw contains 16 teeth. Of these 16 teeth, 4 are cutting teeth or *incisors*, 2 are tearing teeth or *canines* and 10 are grinding teeth. Of these 10 grinders, 4 are called *pre-molars* and the remaining six are called *molars*. The distinction between the pre-molars and the molars is only that the molars are not represented in milk dentition.

Each tooth is firmly embedded in the socket of the jaw. (Fig. 14) The exposed portion of the tooth above the gums is referred to as the *crown*, while the portion within the socket is known as the *root*. The portion between the root and the crown is the *neck*. In the centre of each tooth, there is a cavity, the *pulp cavity*, filled with

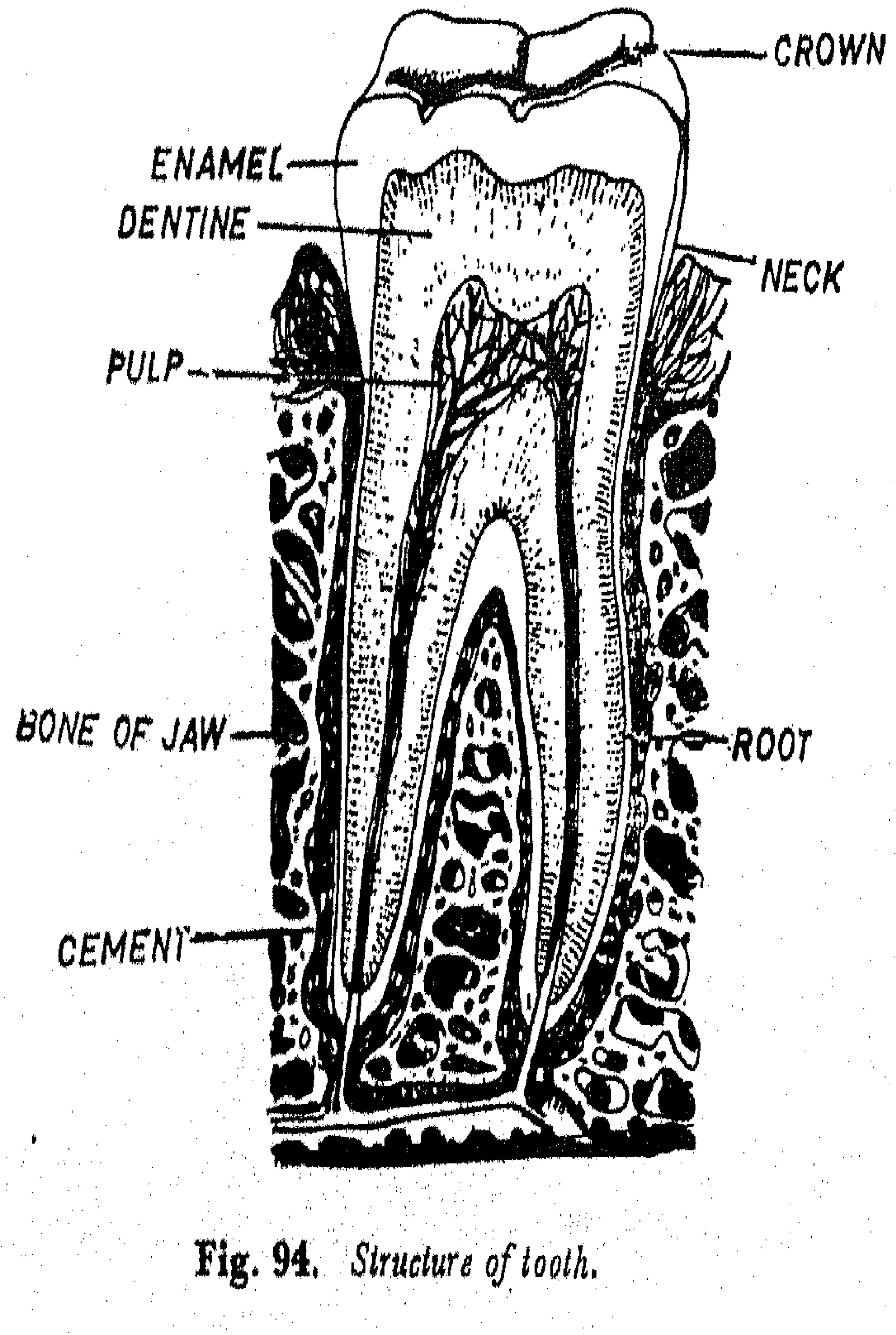


Fig. 94. *Structure of tooth.*

a dental pulp and containing blood vessels and nerve fibres. Around this cavity is a hard elastic substance, the *dentine.* On the crown, the dentine is covered over by a dense white layer, the enamel. At

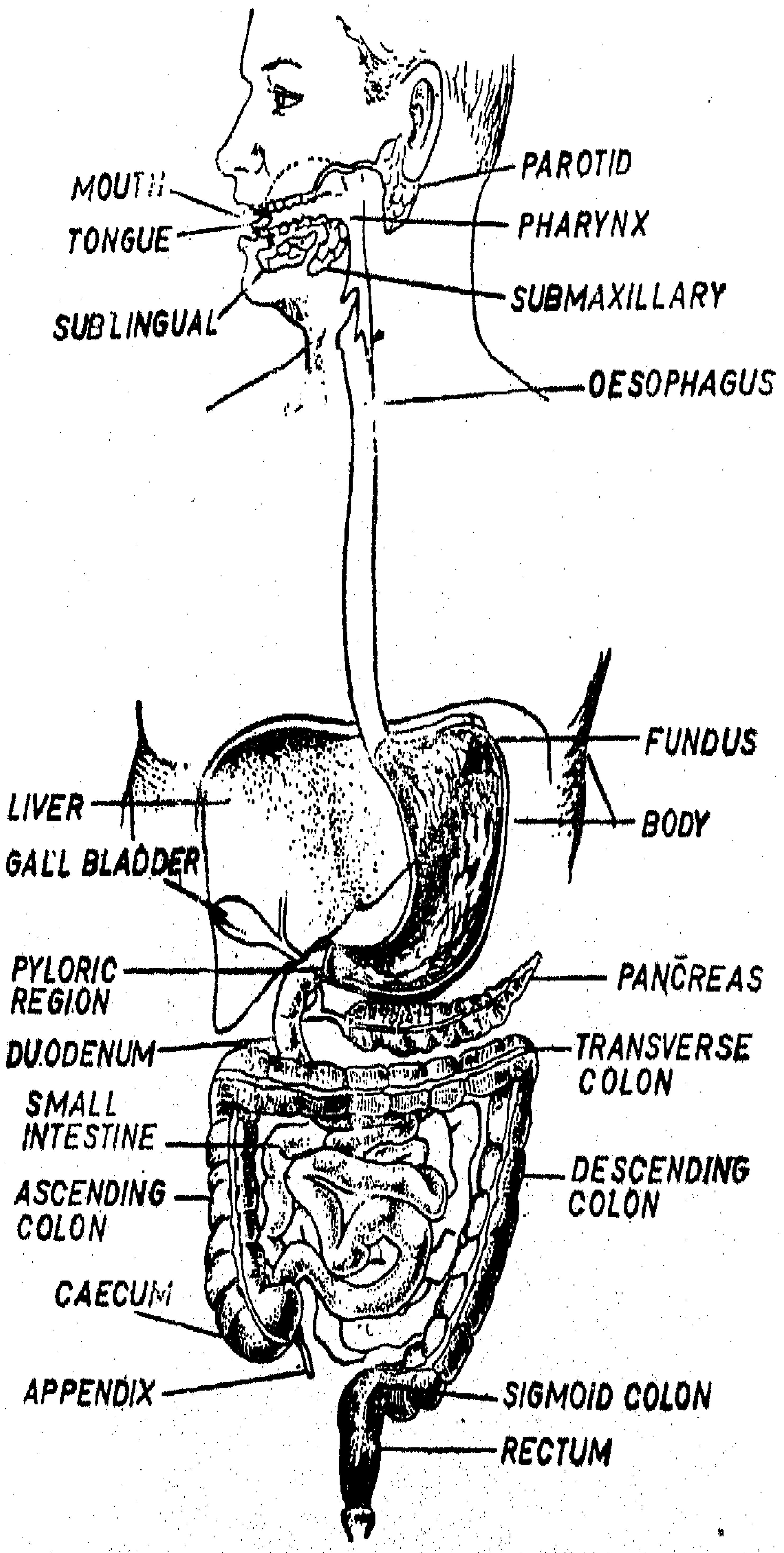


Fig. 95. *Human Digestive system*

the root region, the dentine is covered by a layer of substance called *cement.*

On the floor of the buccal cavity is a fleshy muscular tongue, which is freely movable and is attached at its posterior end. The tongue is an organ of taste and speech. On its upper surface are groups of sensory cells or taste buds. It also helps in the process of chewing or mastication and in swallowing. The roof of the buccal cavity is called *palate.* The anterior part of the palate is hard and is known as hard palate, while the posterior part is soft and is called the soft palate Hanging from the soft palate is a finger like projection, the *uvula.*

The buccal cavity is followed by the next region of the digestive tract called the *pharynx.* (Fig. 95) It is a common passage for food and air, since the wind pipe or trachea also starts from it with the glottis. The pharynx continues downwards into a muscular tube called the *oesophagus.* This is about 10 inches long and extends from the pharynx, through the neck, into the thoracic cavity ; and, piercing the diaphragm (present between the thoracic and the abdominal cavity), it gets connected with the *stomach.*

The stomach is a muscular, highly enlarged part of the digestive canal. It is almost J-shaped and is placed transversely. Posteriorly, the stomach is connected with the tubular intestine The upper end of the stomach, where the oesophagus is connected, is the cardiac end ; the posterior end connected with the intestine (duodenum) is called the *pyloric* end; the middle and larger portion is called the body. The portion of the stomach extended upwards near the cardiac end is termed the *fundus.* Both the cardiac and the pyloric ends are guarded by a ring of circular muscles or *sphincters*, known as the cardiac and the pyloric sphincters respectively. The pyloric sphincter is also referred to as *pylorus* or *pyloric valve.* These sphincters normally are in a state of contraction. The cardiac sphincter prevents the food from getting back into the oesophagus (regurgitation). The pyloric sphincter remains closed and retains the food in the stomach for 5-6 hours, till the gastric digestion, *i. e.*, digestion in the stomach, is completed. Thereafter, the pylorus opens, gradually allowing the semi-digested food (*chyme*) from the stomach into the duodenum. At the region of the pylorus externally, *i.e.*, between the stomach and the duodenum, there is a groove called the pyloric constriction. The stomach is followed by the small intestine.

The *small intestine* is the most important region of the alimentary cannal, for the major portion of digestion as well as the complete absorption of digested food substances takes place here. It is a very much coiled tube of about 24 feet length and 1" to 1½" in diameter. For convenience, it is divided into about three parts, even though there is no external demarcation between these regions. The anterior short curved portion of the small intestine is connected anteriorly with the pyloric end of the stomach and forms a U-shaped structure along with the stomach. This curved portion is the *duodenum* and is about 1 foot in length. This is followed by *jejunum*, about 10 feet long. The remaining 13 feet of the small intestine is called the *ileum*.

The small intestine is connected posteriorly to the next region of the digestive tract, the *large intestine*. At the junction of the small and the large intestine is a blind sac-like region called the *caecum*, to which is appended a worm-shaped tube called the *vermiform appendix*. The appendix has no known function and is considered to be functionless *i.e.*, a defunct, vestigial organ. When it gets inflammated, one has *appendicitis*.

The *large intestine* is much wider than the small intestine and is about 2" to 2½" in diameter and 6 feet in length. It is divided into the *colon* and the *rectum*. The colon shows four regions, the *ascending*, *transverse*, *descending*, and *sigmoid* or *pelvic* colon. The ascending colon runs up on the right side of the abdominal cavity; the transverse colon is present just below the stomach and crosses from the right to left, and the descending colon runs down on the left side to join the sigmoid colon. The colon is followed by the rectum, which opens to the outside by an external opening, the anus. The anus in kept closed by the *anal sphincter* except when the undigested residue *i.e.*, *faeces*, is being egested.

The entire alimentary canal is lined with the mucous membrane. This secretes a slimy substance, the *mucus*. This mucus not only helps in the easy passage of food, but also protects the delicate mucous membrane from being digested by the digestive juices of the different digestive glands. In the region of the stomach and the intestine, the cells of the mucosa are modified in the form of glands, which secrete the digestive juices that help in digestion.

Digestive Glands

The glands, associated with the digestive system and concerned with digestion, are called digestive glands. They are :

(1) Salivary glands, (three pairs), which open into the buccal cavity ;
(2) Gastric glands of the stomach ;
(3) The liver ;
(4) The pancreas; and
(5) Glands of the intestine, known as intestinal glands

Salivary glands. There are three pairs of salivary glands called the parotid, submaxillary and sublingual glands. Their secretion is known as *saliva*, which is poured into the buccal cavity by their independent ducts. The saliva is a colourless viscous fluid, which contains about 99% water and about 1% dense residue composed of mucin or mucus, salts and an enzyme or digestive ferment called the *ptyalin*. The reaction of saliva is mildly alkaline. It helps in softening and lubricating food for the purpose of swallowing. The ptyalin is an enzyme which brings about the digestion of complex carbohydrates (*Polysaccharides*) into simpler forms like maltose (*Disaccharide*).

Gastric glands. The internal lining of the stomach is produced in the form of tubular glands. They secrete the gastric juice, which is poured into the lumen of the stomach. It is acidic in nature. The gastric juice contains about 98% water, a small quantity of HCl (about 0.5), mucin and the enzymes—pepsin and rennin.

Liver. It is the largest gland in the body. It is dark brown in colour and is divided mainly into two lobes, the right and the left. The right lobe is further divided into three lobes. On the ventral side of the right lobe is present a pear-shaped sac, the *gall bladder*, in which the secretion of the liver, the *bile*, is stored. The liver continuously secretes bile, which is taken away from the liver by the hepatic ducts and is stored temporarily in the gall bladder. Here, it gets concentrated. The hepatic ducts coming from the liver lobes and the duct coming from the gall bladder (*i.e.*, the cystic duct), join together to form the common bile duct, which opens into the duodenum. Thus, when food reaches the duodenum, the bile is poured over it.

Bile is greenish, alkaline, watery fluid and has no digestive enzymes. It contains 90% water, bile pigments, bile salts (organic), inorganic salts and a substance called *cholesterol.* The bile pigments are *biliverdin* and *bilirubin.* These are excretory products, since they are produced by the decomposition of haemoglobin from the functionless red blood corpuscles, which are destroyed in the spleen. Bile pigments, along with cholesterol, are removed from the body by way of the faeces (undigested residue of the alimentary canal). Bile helps indirectly in the digestion and absorption of fat, due to the presence of bile salts (*taurocholate* and *glycocholate* of sodium). These salts break up the bigger fat droplets into their smallest size, by reducing the surface tension. This process is known as *emulsification*, whereby the surface area of fat exposed for enzyme reaction is enormously increased. Bile is also antiseptic in nature.

The *liver* by secreting bile, helps indirectly in the digestion of the fat and also in the removal of certain waste matters. Apart from these functions, the liver also serves to store up the excess of glucose from the blood in the form of glycogen (animal starch) with the help of an enzyme, *glycogenase*. This glycogen, which is a complex carbohydrate, is stored in liver cells for future use. Whenever there is a drop in the sugar level in the blood, the stored glycogen is reconverted into glucose in the presence of the same enzyme, the glycogenase, and is given back to the blood. (Glycogen is also stored in the muscles). In the liver, from the excess of amino acids (*i.e.*, digested simplest proteins), the amino group ($-NH_2$) is separated and then oxidized to urea, and is taken to the kidneys through the blood for elimination. This process is known as *deamination*. This is quite an essential process since the excess of amino acids is harmful to the body, and they cannot be eliminated by the kidneys. The liver also contains special cells (*Kauffer's* cells), which ingest and destroy infectious germs entering the body. The toxins (*i.e.*, poisons), introduced by the harmful germs, are neutralised by the special anti-toxins produced by the liver. Thus the liver is one of the busiest, most important and essential organs of the body.

Pancreas. It is also one of the important digestive glands It lies alongside the duodenum. It is greyish pink in colour, leaf like, broad at one end and narrow at the other end. The pancreatic duct and the common bile duct open together into the duodenum. The pancreas is the second largest gland in the body. It produces pancreatic juice which is taken into the duodenum. The pancreatic juice is a clear colourless liquid of an alkaline nature and contains about 98% water, certain organic salts like sodium carbonate and bicarbonates, and three important enzymes, namely, trypsin, amylopsin and steapsin. Scattered amongst the pancreatic cells are groups of small cells. These are called *Islets of Langerhans*. They are ductless or endocrine glands. The secretions of the endocrine glands are called as *hormones*, and these are directly taken away by the blood to be distributed to the different parts of the body. The hormone secreted by the islets of Langerhans is *insulin*, it controls the sugar metabolism of the body and is responsible for maintaining a constant level of glucose in the blood. Any deficiency in insulin brings about a disease known as *diabetes* in man, in which the glucose accumulates in the blood and is given out of the body through the kidneys.

Intestinal glands. The intestinal glands are numerous and are situated in the internal lining of the small intestine. They secrete the intestinal juice, known as *succus entericus*. It is alkaline in nature and contains water, salts, mucus and the enzymes like erepsin, maltase, sucrase, lactase and lipase. The intestine also secretes another enzyme, the *enterokinase*, which is an activator of the pancreatic juice.

Digestion

With the exception of the mineral salts and simple carbohydrates like glucose, most of the solid foods are incapable of passing through the living membrane of the alimentary canal, since they are insoluble and indiffusible in their complex form. In order to make them soluble and diffusible, they must be broken down into their simple molecular forms

Thus digestion is a process in which highly complex food substances like proteins, carbohydrates and fats are simplified into their smallest molecules, so that they could diffuse through the mucous membrane of the alimentary canal. This breaking down of the larger molecules of food is done by the action of the digestive enzymes or ferments present in the digestive juices, secreted by the various digestive glands.

The digestion is a process of hydrolysis, wherein each molecule of a complex substance takes up a molecule of water and dissociates itself, thus progressively reducing to the simplest diffusible form. The action of any enzyme is only to increase the rate of this hydrolysis. Thus a digestive enzyme is only an organic catalyst, which does not get digested or involved in the process of digestion. At the end of digestion, the enzyme remains the same without being used up in the process.

Enzymes

(1) **Enzymes are bio-catalysts produced by the protoplasm of any living cell.**

(2) **Enzymes are proteins by nature.**

(3) **They bring about chemical changes without themselves undergoing any change.**

(4) They are required in small quantities to bring about the necessary reaction, for they are not used up in the reaction.

(5) They merely accelerate or enhance the rate of chemical reactions.

(6) They act only in a specific medium; some act in an alkaline, some in acidic, and others in neutral medium.

(7) They are specific in their reactions, since any particular enzyme can act upon only on one type of substrate.

Digestive enzymes are of three kinds, for there are three kinds of complex foods (*substrates*) to be digested :

(a) **Proteolytic** (*i. e., Proteases*) : Those which act upon proteins.

(b) **Amylolytic** (*i.e., Amylases*) : Those which act upon carbohydrates (*i.e., starch i.e., Amylum*).

(c) **Lipolytic** (*i.e., Lipases*): Those which act upon fats.

(8) Most of the enzymes are intracellular. Some enzymes like digestive enzymes are extracellular.

(9) They are more effective at a particular temperature called the optimum temperature.

(10) Above a particular maximum and below a particular minimum temperature, the enzymes are not functional. They are also destroyed at high temperatures—70°C-100°C.

(11) They are reversible in action; *e.g.,* Glycogenase can convert the glucose to glycogen and *vice versa.*

$$\textit{Glucose} \xrightleftharpoons{\textit{Glycogenase}} \textit{Glycogen}$$

Digestion in Man

Digestion in the mouth. Digestion begins in the mouth where food is chewed or masticated with the help of teeth and mixed up with saliva. By the help of the muscular tongue and the cheeks, the food is rolled up into balls called *boluses* (singular, *bolus*) before being pushed down into the gullet. The saliva, which is akaline, contains an enzyme, *ptyalin.* Ptyalin acts in an alkaline medium. It acts upon complex carbohydrate (polysaccharide) like starch and converts it into a sugar, the maltose (disaccharide). It is thus an amylolytic enzyme.

$$\textit{Starch (Carbohydrate)} \xrightarrow{\textit{Ptyalin}} \textit{Maltose}$$

The action of ptyalin can go in the stomach for some time, until it is made inactive by the acidity of the gastric juice.

The food is then swallowed. In this process of swallowing, it is prevented from entering the trachea by the epiglottis. It then passes into the oesophagus. It travels through the oesophagus by the peristaltic movements of its wall. The peristaltic movements or *peristalsis* (Fig. 96) is a wave of relaxations followed by a wave of contractions in a muscular tube, starting from one end and proceeding to the other. The contraction of the muscular wall takes place posterior to, and the relaxation in front of, the substance passing through the tube. Peristalsis is common not only to the alimentary canal but also to all the muscular tubes in the body. Due to presistalsis food reaches the stomach through the oesophagus.

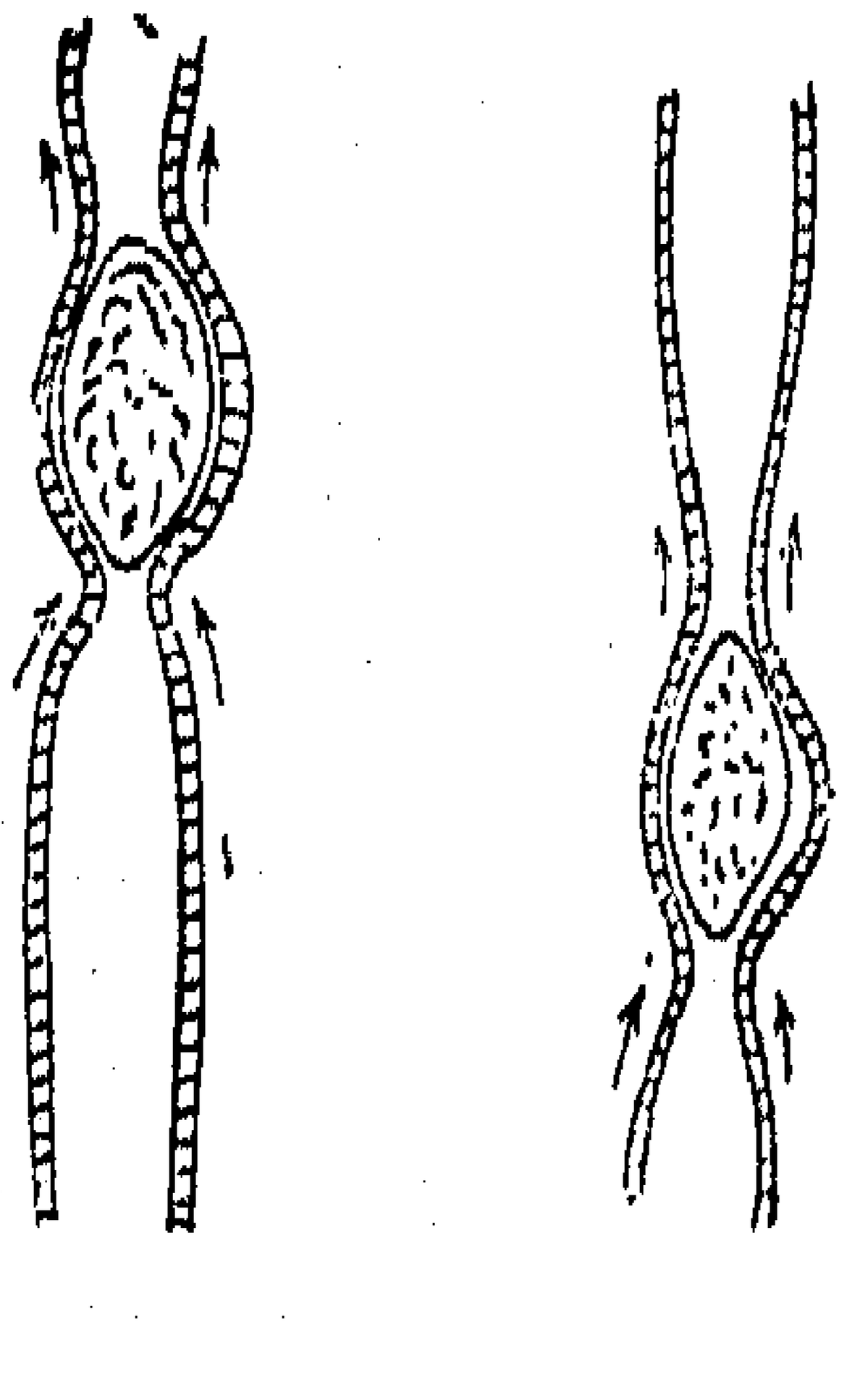


Fig. 96. *Peristalsis.*

Gastric digestion. In the stomach, the food is retained for about 5 to 6 hours, where it is thoroughly mixed with the gastric juice by the churning movements of the stomach. The gastric juice is secreted by the gastric glands of the stomach and it is a colourless transparent liquid of an acidic reaction. This is due to the presence of hydrochloric acid (about 0.5%). It also contains a small amount of mucus and certain enzymes.

Enzyme *pepsin* (proteolytic enzyme of the gastric juice) converts the proteins to their simpler forms like proteoses and peptones. Pepsin becomes active only in the presence of an acid. Therefore, HCL is necessary for gastric digestion. HCL is also antiseptic, which inhibits bacterial growth. In addition to pepsin, the gastric juice of young individuals also contains an enzyme *rennin* (*chymosin*). This enzyme curdles the milk after which pepsin acts upon milk protein *caesin* and converts it into proteoses and peptones. The presence of rennin in the adult human stomach is doubtful, for it has been established that pepsin can also coagulate the milk.

The third enzyme present in the gastric juice is *lipase* (lypolytic enzyme). Under the action of this enzyme, the fats which are in a state of emulsification (egg-yolk, etc.), are split up into fatty

acids and glycerol (*glycerine*). Lipolytic action in the stomach of adults is weak; in the young ones, feeding on milk, this process is of great importance.

The food in the stomach, after being subjected to muscular and enzymatic action, gets partly digested. This semi-digested, semi-liquid, acidic food of the stomach is called *Chyme.*

Chyme is then allowed to pass into the next portion of the alimentary canal, namely, the duodenum, by the relaxation of the pyloric sphincter (pylorus) of the stomach.

Intestinal digestion. The entry of food in the duodenum stimulates the secretion of bile and the pancreatic juice.

The pancreatic juice contains :

(1) *Trypsin* (proteolytic enzyme) ;

(2) *Amylopsin* (Amylolytic enzyme) ;

(3) *Steapsin* (Lipolytic enzyme) ; and

(4) Also a small quantity of sodium carbonate and sodium bicarbonate.

The pancreatic enzymes act only in an an alkaline medium. The acidic chyme is first of all neutralised and rendered alkaline by the action of salts present in the bile, pancreatic and intestinal juices.

Trypsin is present in an inactive state called *Trypsinogen.* This trypsinogen is activated and converted into trypsin only when it is mixed with another enzyme, *enterokinase* present in the intestinal juice.

Trypsin now acts upon the undigested protein residue and semi-digested proteins, namely, the proteoses and peptones, and converts them into peptids. Peptids may be poly, tetra, tri, or dipeptids, depending upon the number of amino acid molecules that they are formed of.) Some of the peptids are also further simplified to amino acids by the trypsin.

Amylopsin hydrolyses starch to maltose. Maltase, an enzyme which converts the maltose into glucose, is also found in small amounts in the pancreatic juice.

The action of bile has been already discussed. It has no digestive enzymes ; yet it helps in the digestion and absorption of fats. The emulsified fats are subjected to the action of steapsin and are simplified into fatty acids and glycerol.

The food, which is acted upon by bile and the pancreatic juice, is being simultaneously acted upon by the intestinal juice, *i.e., succus entericus.*

The intestinal juice contains mucus, carbonates and bicarbonates of sodium, and the following enzymes

(1) *Peptidases* (*Erepsin*), which act upon the peptids and simplify them into amino acids, which are the end products of protein digestion. The amino acids are capable of being absorbed by the mucous lining of the intestine.

(2) Amylolytic enzymes like *maltase, sucrase, lactase* which act on the disaccharides, (*e.g.,* maltose etc.) and convert them into glucose, which is the end product of carbohydrate digestion. Glucose is readily absorbed by the intestinal wall.

(3) *Lipase* is also present in the intestinal juice which brings about the digestion of any fats that may have been left undigested by the steapsin. These fats are broken down into fatty acids and glycerol.

Thus, by the time the complex food substances, taken into the alimentary canal, reach the lower portion of the small intestine, they are completely digested into their simplest forms and made soluble and absorbable. The completely digested alkaline liquid food is called *Chyle.*

The main function of the large intestine is to store the undigested food (*i. e.,* faeces), from which the excess of water is absorbed by its mucosa. This faeces is egested through the anus.

Summary of Digestion

I. Buccal digestion

Starch (carbohydrates) $\xrightarrow{\text{Ptyalin}}$ Maltose.

II. Gastric digestion

(i) Milk $\xrightarrow{\text{Rennin}}$ Curdles the Milk and produces Caesin.

(ii) Proteins (and also Caesin) $\xrightarrow{\text{Pepsin}}$ Proteoses and Peptones.

III. Intestinal digestion

(1) *Bile* :

Fat $\xrightarrow{\text{Bile salts}}$ Emulsification of fat.

(2) *Pancreatic juice* :

(i) Undigested Proteins, Proteoses & Peptones $\xrightarrow{\text{Trypsin}}$ Peptids & amino acids.

(ii) Starch $\xrightarrow{\text{Amylopsin}}$ Maltose.

(iii) Fats (emulsified) $\xrightarrow{\text{Steapsin}}$ Fatty acids and Glycerol.

(3) *Intestinal juice* :

(i) Peptids $\xrightarrow{\text{Peptidases (Erepsin)}}$ Amino acids.

(ii) Maltose $\xrightarrow{\text{Maltase}}$ Glucose.

(iii) Fat $\xrightarrow{\text{Lipase}}$ Fatty acids and Glycerol.

Absorption. Absorption begins in the stomach, whose mucosa absorbs the water and salts to some extent. However, the major absorption is done by the mucosa of the small intestine, where alone all the complex foods are simplified. This absorption takes place through the internal lining of the intestine into the blood and lymph.

Since water, mineral salts and vitamins do not need any digestion before absorption, they are directly taken into the blood system.

The inner surface (mucosa) of the small intestine is thrown into number of small finger-like processes called *Villi* (singular, *Villus*) (Fig. 97, 98). This increases the area of absorption of the intestine. Each villus contains a network of arterial and venous capillaries. The arterial branch brings oxygenated blood to the intestine, while the venous branch takes away deoxygenated blood, which contains a large amount of digested food. Also, in the centre of each villus, there is a *lacteal*, which is a lymph capillary. The surface of the villus is covered with columnar epithelial cells.

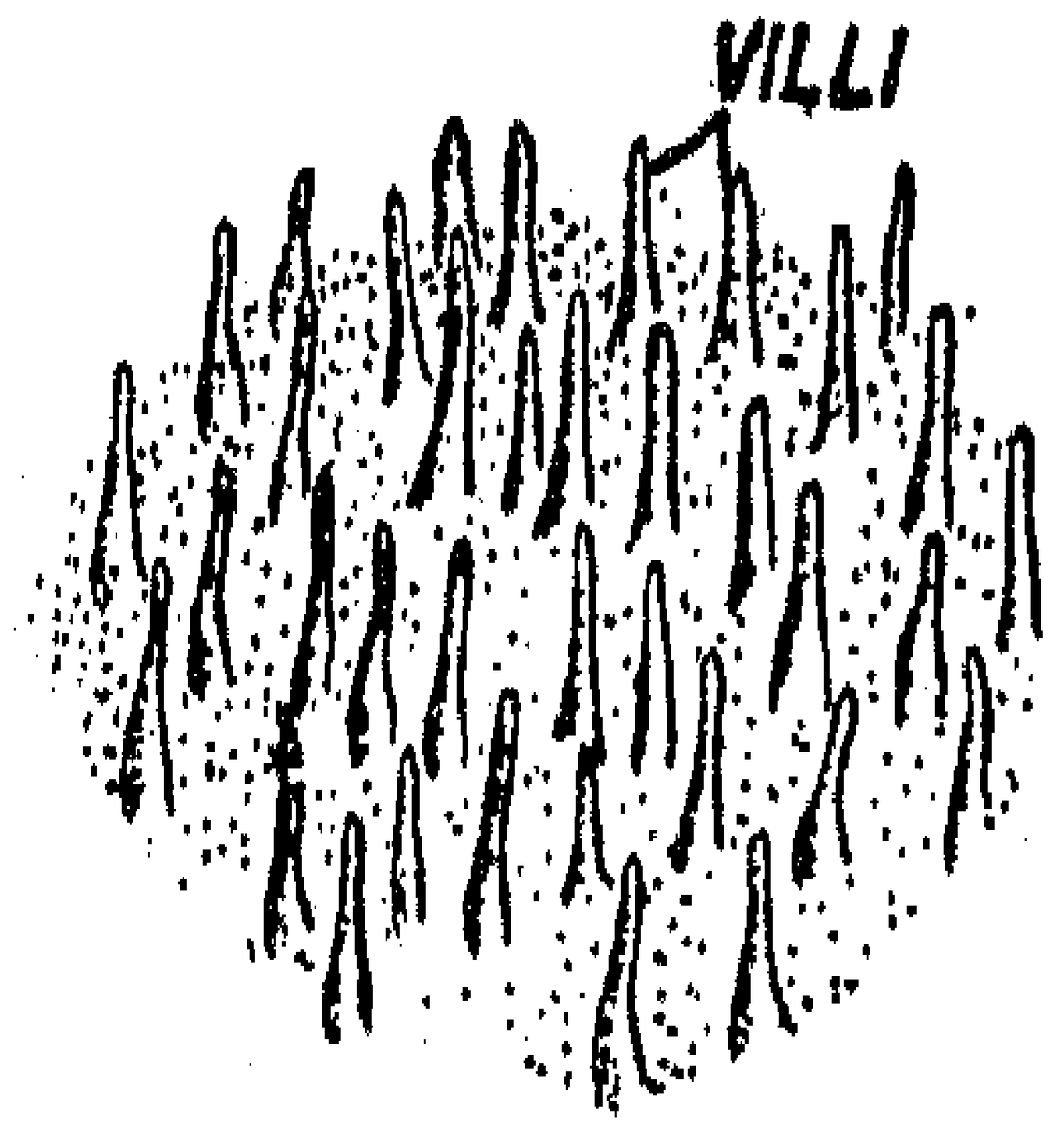


Fig. 97. *Villi*

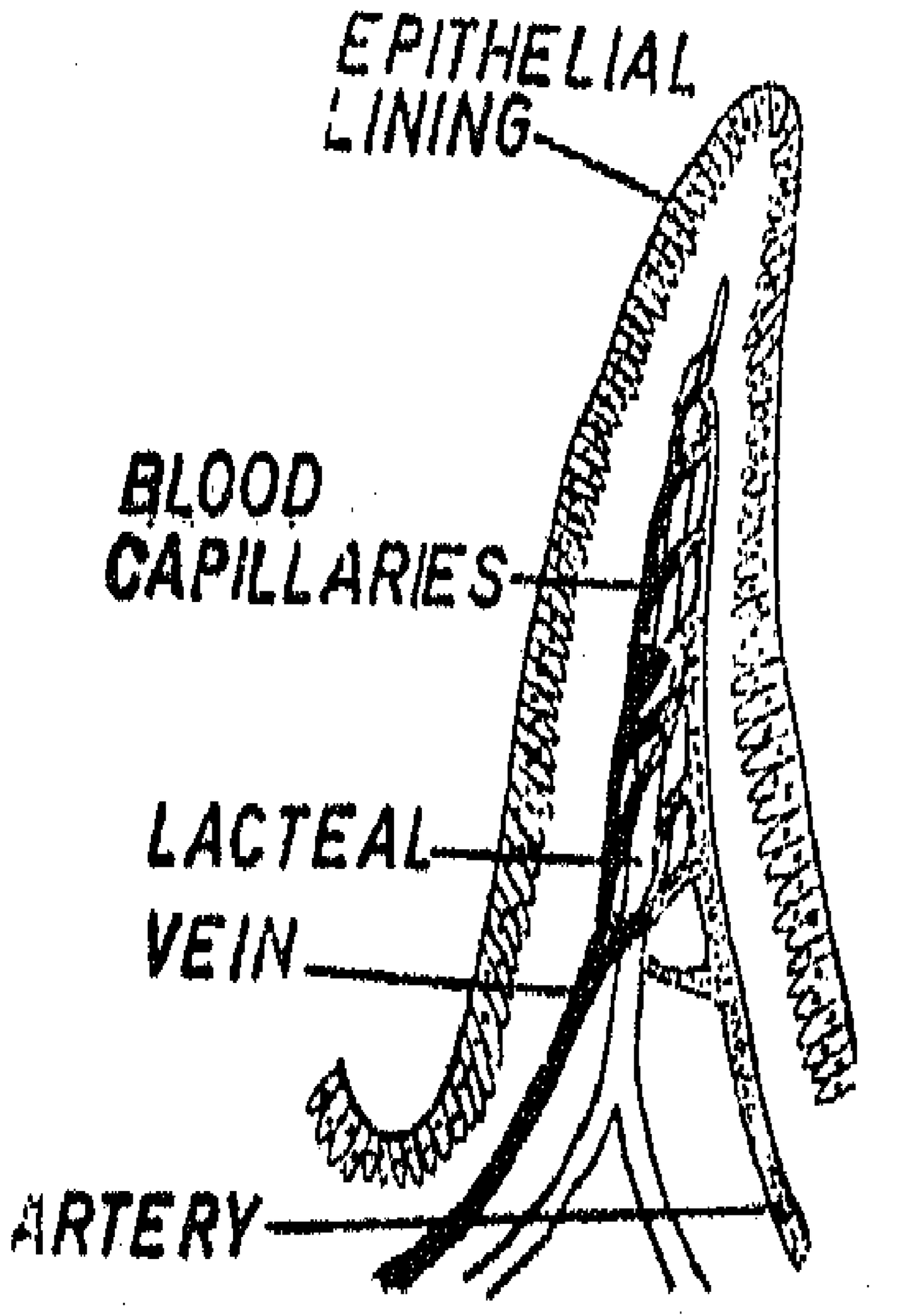


Fig. 98. *Villus*

Water, amino acids and glucose are absorbed into the blood capillaries through the lining of the villi. The fatty acids and glycerol enter the wall of the intestine ; there, they combine once again in the presence of enzyme lipase to form neutral fat, and then they are absorbed in the lacteals. But for the bile salts, most of the fatty acids would remain unabsorbed. Ultimately, they find their way into the blood stream since the main lymphatic trunks, to which these lacteals join open into the main blood vessels entering the heart.

Transportation. The digested foods, like the glucose and amino acids, are first taken to the liver by the system of veins, forming the *hepatic portal system*, coming from the various parts of the alimentary canal, including the veins from the small intestine. From the liver the blood, rich in digested food, reaches the heart, from where these substances are distributed to the different cells of the tissues of the body, by way of the arterial system.

Assimilation. In individual cells, the amino acids are mostly converted into protoplasm, the body-building substance. The glucose and fats are mostly oxidized, during cellular respiration, to liberate the necessary energy for metabollic activities.

Excess of amino acids are *deaminated* in the liver and removed from the body in the form of urea. Excess of glucose is stored in the liver cells as glycogen for future use. Excess of fats is deposited beneath the skin as subcutaneous fat which serves as reserved food.

SUMMARY

1. Alimentary canal starts with mouth and ends with the anus.
2. It is concerned with nutrition.
3. Digestion means transformation of complex and insoluble food substances into the simple and soluble products with the help of enzymes.
4. The three regions where digestion takes place are, (i) Mouth (ii) Stomach and (iii) Small intestine.
5. In mouth very little of carbohydrate is reacted upon and converted into maltose by enzyme ptyalin secreted by salivary glands.
6. In stomach the proteins are transformed into proteoses and peptones due to the enzyme Pepsin which reacts only in the acidic medium.
7. Bile is not an enzyme. Its role is only to emulsify the fat. It is secreted by liver and stored in gall bladder.
8. Pancreatic juices contain enzymes like Trypsin, Amylopsin and steapsin which react on proteins, carbohydrates and fat respectively.
9. Intestinal juices contain enzymes like Peptidase, Maltase and Lipase.

10. With the help of the above enzymes digestion is completed in small intestine.
11. This food is absorbed by villi, circulated and passed on to each cell which later on is assimilated by the cell.

BIOLOGICAL WORDS

- Alimentary canal
- Enzyme
- Saliva
- Ptyalin
- Chyme
- Chyle
- Gastric Juice
- Duodenum
- Ileum
- Gall Bladder
- Bile
- Colon.

QUESTIONS

1. What is digestion? Describe the alimentary canal of man and add a note on the digestion of Proteins.
2. Describe briefly the structure and functions of the liver in man.
3. Write short notes on :—
   (a) Bile, (b) Peristalsis, (c) Buccal Cavity, (d) Pancreas, (e) Salivary glands of man, (f) Gastrtc digestion, (g) Teeth.
4. Give the actions of the following enzymes.
   (a) Trypsin, (b) Ptyalin, (c) Pepsin, (d) Maltase, (e) Lipase, (f) Amylopsin.
5. Fill in the blanks :—
   (i) Pancreatic juice contains, ———, ———, ——— and ——— enzymes.
   (ii) The hardest substance in the tooth is ———.
   (iii) ——— controls percentage of sugar in the blood.
   (iv) The tongue is concerned with ——— and ———.
6. Give one important function of following :—
   (i) Canine, (ii) Tongue, (iii) Stomach, (iv) Incisor, (v) Liver (vi) Large intestine, (vii) Saliva, (viii) Villus, (ix) Bile, (x) Molars, (xi) Epiglottis,

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Organs of Nutrition in Other Animals

8

Digestive System of Rabbit

Rabbits are rodents, feeding mainly on plants, a diet rich in cellulose. Accordingly, the digestive system shows some modifications.

Alimentary Canal. It starts with the mouth, which is bounded by a pair of fleshy lips. (Fig. 99) The mouth opens into the buccal cavity bounded by the upper and lower jaws. Both the jaws bear teeth of different kinds as in humans. The canines are absent. There is a muscular tongue on the floor of the buccal cavity. Opening into the buccal cavity are the ducts of 4 pairs of salivary glands. The buccal cavity leads into the pharynx, into which also opens the glottis. The pharynx is followed by the oesophagus, which is long and narrow. The oesophagus pierces the transverse diaphragm and opens into the stomach, which is transversely placed. The stomach has an anterior cardiac end and a posterior pyloric end. Both the cardiac and the pyloric ends are guarded by cardiac and pyloric sphincters respectively, which control the passage of food into and out of the stomach.

The stomach is followed by the small intestine. It is a long, narrow and much coiled tube about 8 feet in length. The anterior U-shaped loop is the duodenum. The rest is the ileum, which ends in a rounded sac, called the *sacculus rotundus*. This sacculus rotundus is connected with a spirally ridged structure, the *caecum*, which is very well developed in the rabbits and is much longer than in the carnivores and man. It is about 20" long. At the distal end of this caecum is a finger-like process, the *vermiform appendix*, which is about 4" in length. The caecum is very well developed in herbivorous animals and contains certain bacteria that digest cellulose (a highly complex carbohydrate), ordinarily difficult to digest.

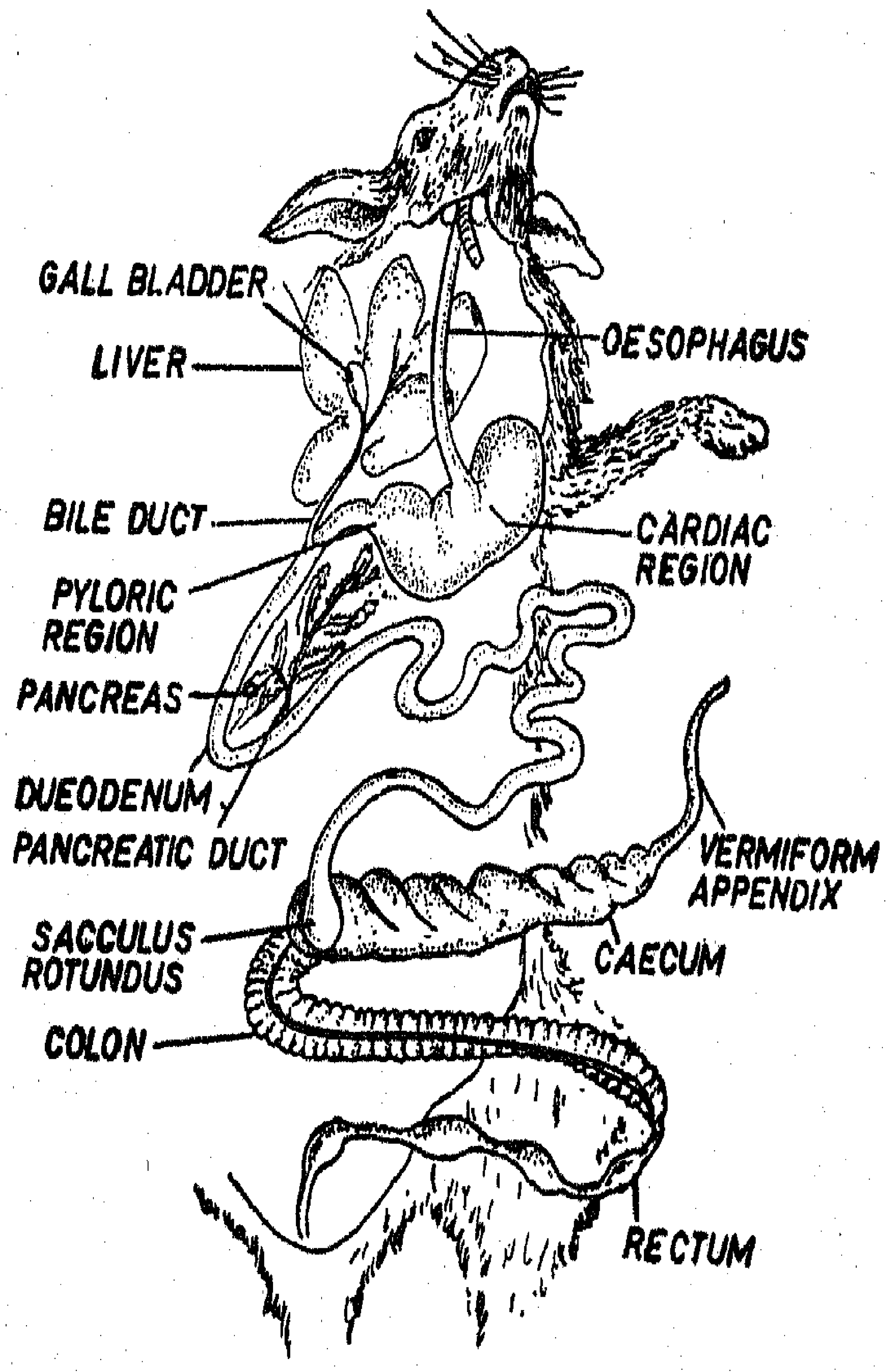


Fig. 99. *Rabbit—Digestive System*

Connected to the sacculus rotundus is the colon, the next part of the alimentary canal. This is about $1\frac{1}{2}'$ long and is sacculated into a number of small sacs. This is followed by the rectum, which is about 2—2 ' long. The rectum is beaded in which the faecal matter is formed into small pellets. The rectum opens to the exterior by the anus. The caecum, colon and rectum together form the large intestine.

Digestive Glands. The accessory glands associated with the digestive tract are mainly salivary glands, liver and pancreas.

The *Salivary Glands* are 4 pairs opening into the buccal cavity. These glands are the parotid, the infraorbital, the submaxillary and the sublingual.

The *liver* is made up of 5 lobes and is dark red in colour. There is a gall bladder. The hepatic ducts of the liver lobes and the cystic duct of the gall bladder unite to form the common bile duct, which opens separately at the dorsal aspect of the duodenum just after the pylorus.

The *pancreas* is a diffused gland present in the duodenal loop. The pancreatic duct does not open along with the common bile duct but opens separately into the ascending arm of the duodenum.

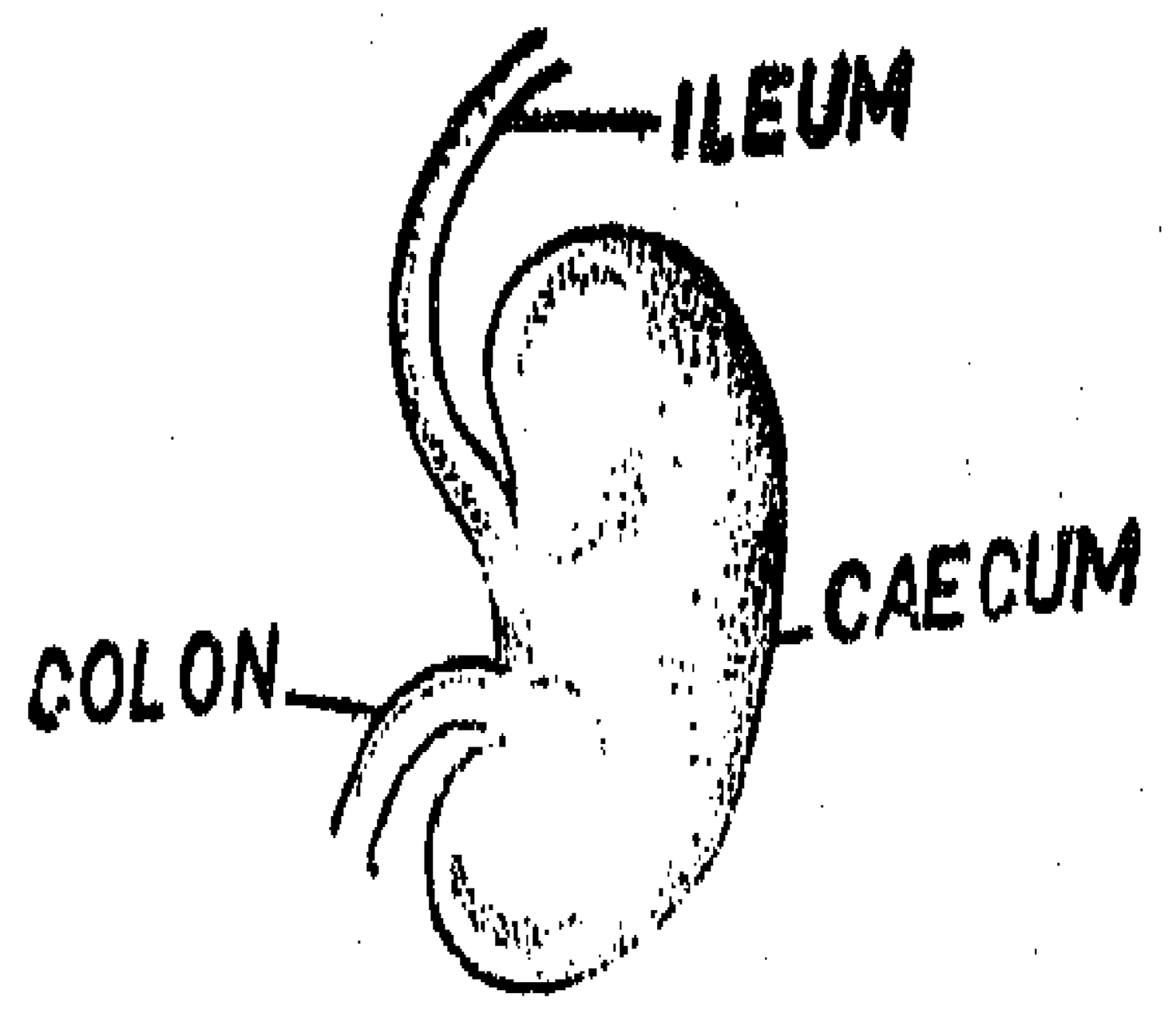


Fig. 100. *Rat—Caecum*

(The digestive system of the *rat* is almost similar to that of the rabbit, except that the caecum (Fig. 100) is comparatively smaller and there is no gall bladder.)

Ruminant Stomach

In accordance with the type of feeding habits in certain herbivorous mammals like the cow, sheep, camel, etc., the stomach is much modified. The rest of the digestive system is built up on a typical vertebrate plan.

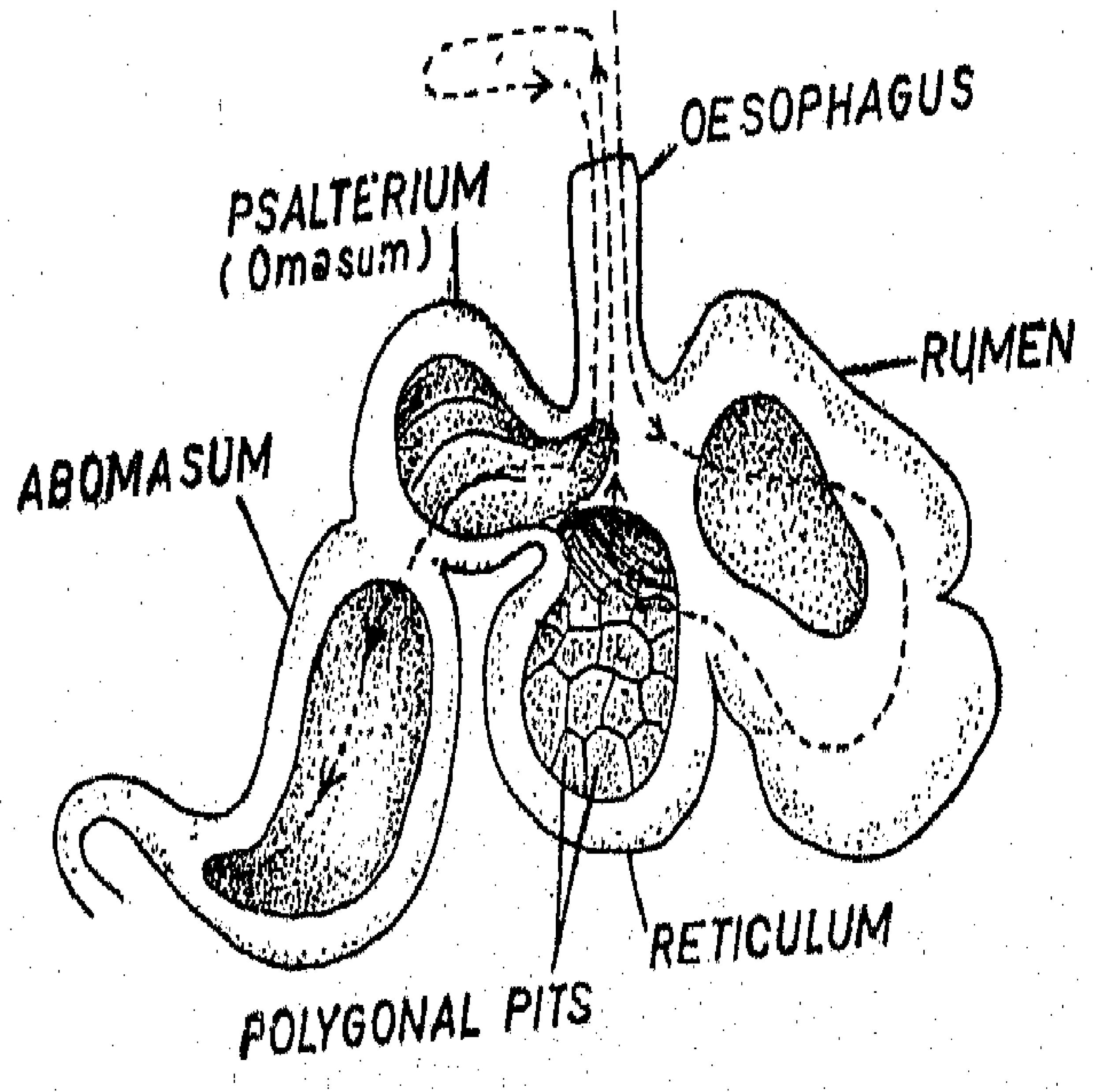


Fig. 101. *Ruminant Stomach*

They graze and hurriedly swallow the food without or with little mastication. When at rest, they bring the food back into the buccal cavity (*i.e.*, regurgitate) and rechew it leisurely. This chewing, of the regurgitated food or cud is known as *rumination* or cud-chewing, and the animals are called cud-chewing animals or *ruminants.* Because of this kind of feeding, the stomach of the ruminants is modified. (Fig. 101).

The stomach is an extremely large bag, made up of 4 chambers : (1) *Rumen* ; (2) *Reticulum* ; (3) *Psalterium* or *Omasum* ; and (4) *Abomasum.*

The *rumen* is the first chamber where the food that is swallowed hurriedly is stored. Here the food also undergoes fermentation. The *reticulum* is the next chamber which has an inner surface raised in the form of honeycomb markings, *i.e.*, reticulations. When the animal is taking rest, the food from the rumen passes into the reticulum, where it is moulded into round boluses because of the hexagonal shallow pits of the inner surface. The cud, in the form of boluses, is sent back once more into the buccal cavity through the oesophagus. Here it is rechewed, completely masticated and mixed up with more saliva. This masticated food is sent down the oesophagus, but this time through a narrow groove present in the lower end of the oesophagus into the third chamber, the *psalterium* or omasum. This chamber acts as a filter, since its inner surface is raised into a number of leaf-like folds. The fourth chamber is the *abomasum.* The food filtered in the psalterium enters the abomasum, which is the real glandular stomach, secreting the gastric juice, which brings about digestion. The food that is semi-digested in the stomach is then passed on to the intestine.

Thus the first two chambers (*i.e.*, the *rumen* and the *reticulum*) are the storage chambers, the third is the filtering chamber and the last is the digestive chamber.

Digestive System of Bird (Pigeon)

These birds are *graminivorous* as they feed upon hard grains, seeds and small fruits. The digestive system shows several modifications for the feeding and flying habits.

The alimentary canal (Fig. 102) begins with the mouth, which is bounded by a pair of horny beaks. The teeth are absent so as to reduce the weight of the body. There is a pointed tongue

in the buccal cavity. The pharynx leads into the oesophagus, whose middle part dilates into a bilobed storage chamber called the *crop*. In the crop, the grains, which are swallowed without mastication, are stored. There are no glands in the crop, but the grains become softened. (During the breeding season, the inner cells lining the crop degenerate and form a milky substance commonly known as "pigeon's milk". This is formed in both male and female, and is fed to the young ones.) The oesophagus leads into the next chamber, the stomach. It consists of two parts, namely, the *proventriculus* and the *gizzard.* The proventriculus is glandular and secretes the gastric juice. The gizzard is a biconvex, disc-like, powerful structure. It has muscular walls and its inner lining has horny ridges which help in grinding the

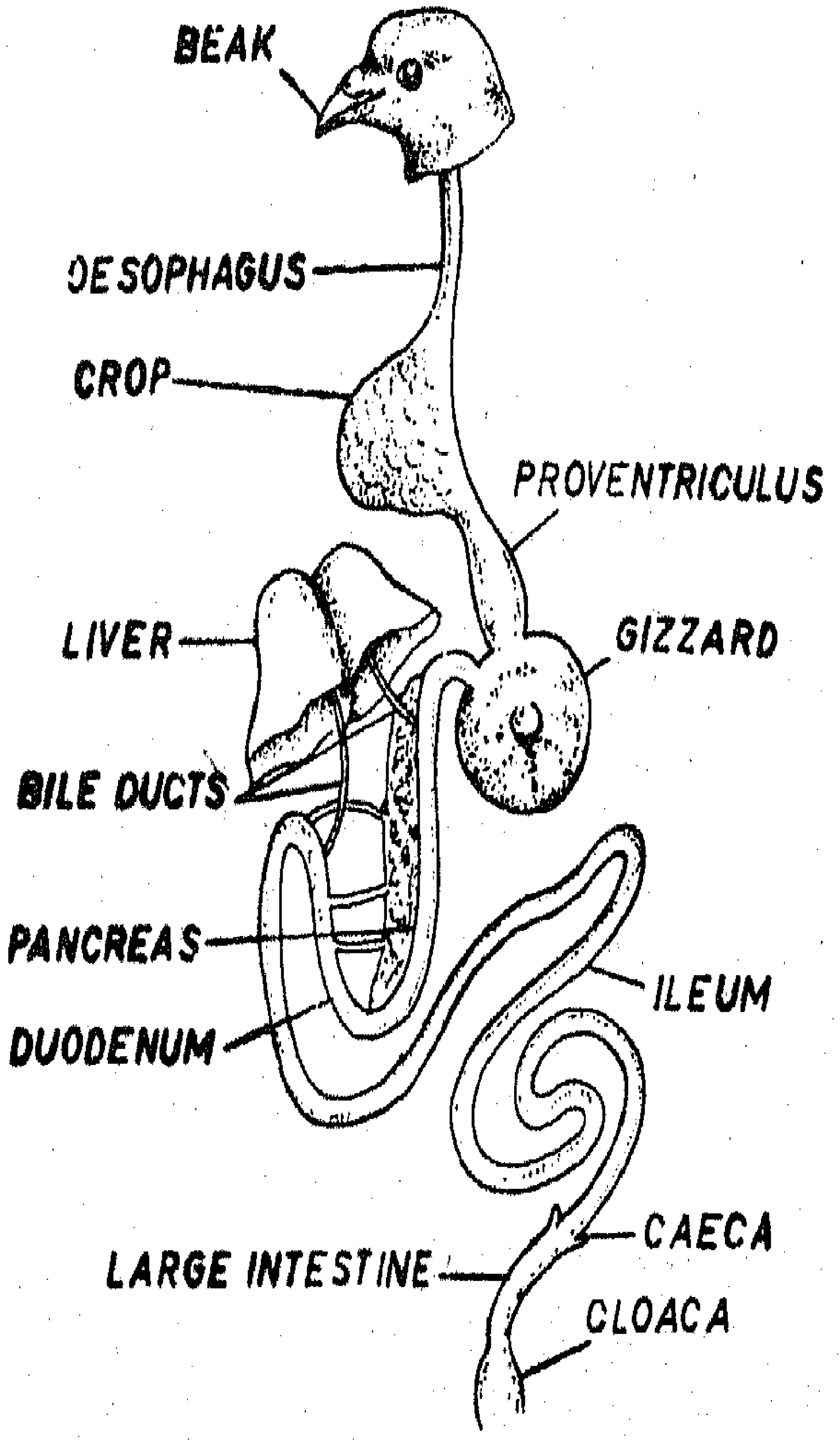


Fig. 102. *Pigeon–Digestive System*

food. This is further aided by the presence of small stones or pebbles which the birds swallow from time to time during feeding.

Following the gizzard is the small intestine, which, as in all other vegetarian animals, is a very long tube. Its proximal part, the duodenum, forms a loop enclosing the pancreas. The rest of the small intestine is called the ileum, which is coiled. The large intestine is very short, about two inches in length. A pair of short rectal caeca lies at the junction of the small and large intestines. The large intestine opens into the cloaca. It is a common chamber, into which not only the rectum but also the ducts of the excretory and the reproductive systems *i. e.*, the urinogenital ducts, open. The cloaca is absent in mammals, for the anal opening and the urinogenital openings are separate. The cloaca, in turn, opens to the outside by the cloacal aperture.

The *liver* is a bilobed structure. The bile from each lobe is taken by its own bile duct into the duodenum. There is no gall bladder in common pigeon. (It is present in some birds as well as in some other species of pigeon.)

The pancreas is a compact gland lying in the loop of the duodenum, into which is poured the pancreatic juice by three pancreatic ducts.

Nutrition in Amoeba

The amoeba is an acellular animal. There is no differentiation of the body into tissues and organs. Yet all the complex physiological functions are carried on in this organism by special regions of the referred to as *organelles.*

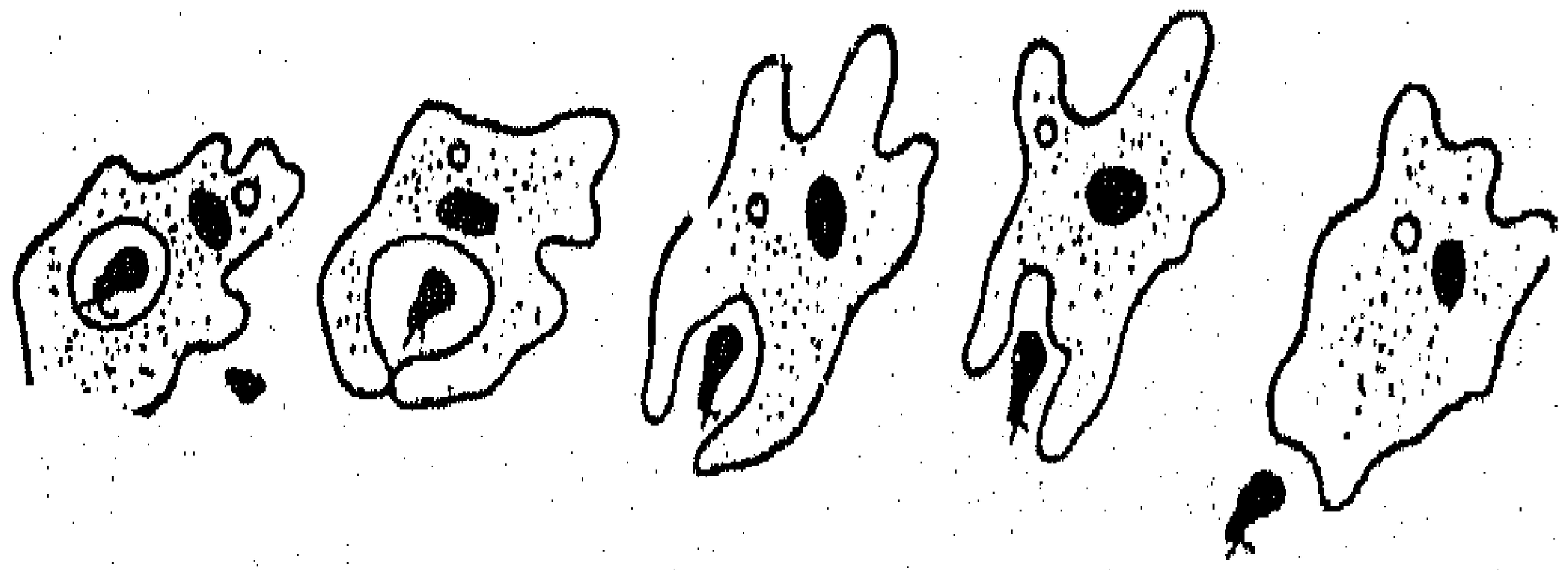


Fig. 103. *Amoeba—Ingestion*

Nutrition in the amoeba is holozoic. The digestive function is performed by organelles called "food vacuoles". It lives on microscopic organisms like diatoms, bacteria, etc. The food is ingested at any point of the cell surface. (Fig. 103) There is no special mouth. When the animal comes into contact with any organism, the pseudopodia are thrown around the food particle in such a way that it becomes completely surrounded. When the pseudopodia of the opposite sides surrounding the food particle meet one another, the plasma membrane between them gets dissolved, thus ingesting the food particles within its cytoplasm. At this time, a film of water surrounding the food particle is also taken in. In this droplet of water, the food particle remains until it undergoes digestion. This structure is called as the food vacuole and it serves as a temporary site for digestion. Due to the streaming movement of the cytoplasm, it is kept in constant circulation. Into this food vacuole, various digestive enzymes capable of digesting proteins, carbohydrates and fats, are secreted from the surrounding cytoplasm. The reaction in the food vacuole is acidic in the beginning, during which the prey, if living, is killed. Later on, it becomes alkaline, and the food is completely digested. The digested food is then absorbed into the cytoplasm by diffusion and is assimilated. The undigested residue is left behind as the animal moves away, and thus it is egested from any point of the cell surface.

As the digestion is carried out inside the cell, the process is called *intracellular* digestion. Intracellular digestion is the only possible method of digestion in all acellular animals.

Nutrition in Hydra

The hydra is a multicellular animal, whose body wall is diploblastic (Fig. 106), *i.e.*, it is made up of two layers of cells. The outer layer is called the ectoderm and the inner layer the endoderm. In between these two layers, there is a middle jelly, the mesoglea, which is non-cellular. The body of Hydra is cylindrical (Fig. 105). At its anterior free end, there is an opening, the mouth. The mouth is raised on a conical elevation, the *hypostome.* It is surrounded by 6 to 8 hollow tentacles. This mouth leads into a central cavity, where digestion takes place. This cavity is referred to as the *coelenteron* or *Gastro-vascular cavity.* The coelenteron is lined by endodermal cells. It has only one opening the mouth, there being no separate anus. The endoderm layer consists of different types of cells like (1) gland cells, which secrete mucus and digestive enzymes ; (2) flagellated cells, which have long flagella with the help of which the food is mixed with digestive juices ; and (3) certain nutritive cells, with pseudopodia, which can ingest and digest the food particles.

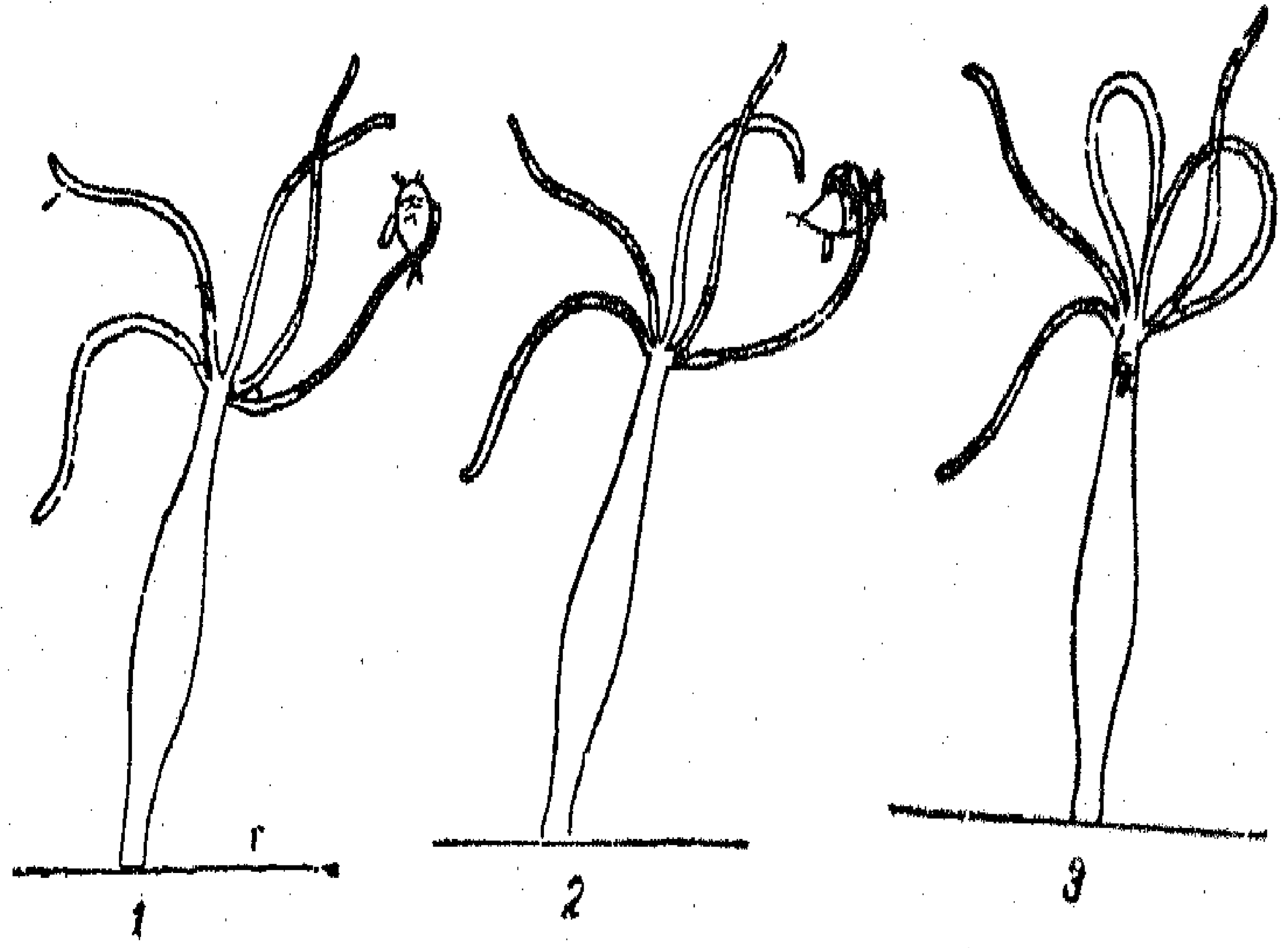


Fig. 104. *Hydra—Ingestion*

The outer ectoderm has certain special cells called stinging cells or *nematocysts,* which contain a poisonous liquid which, when injected through the fine needle-like stings into the body of the prey, paralyses it.

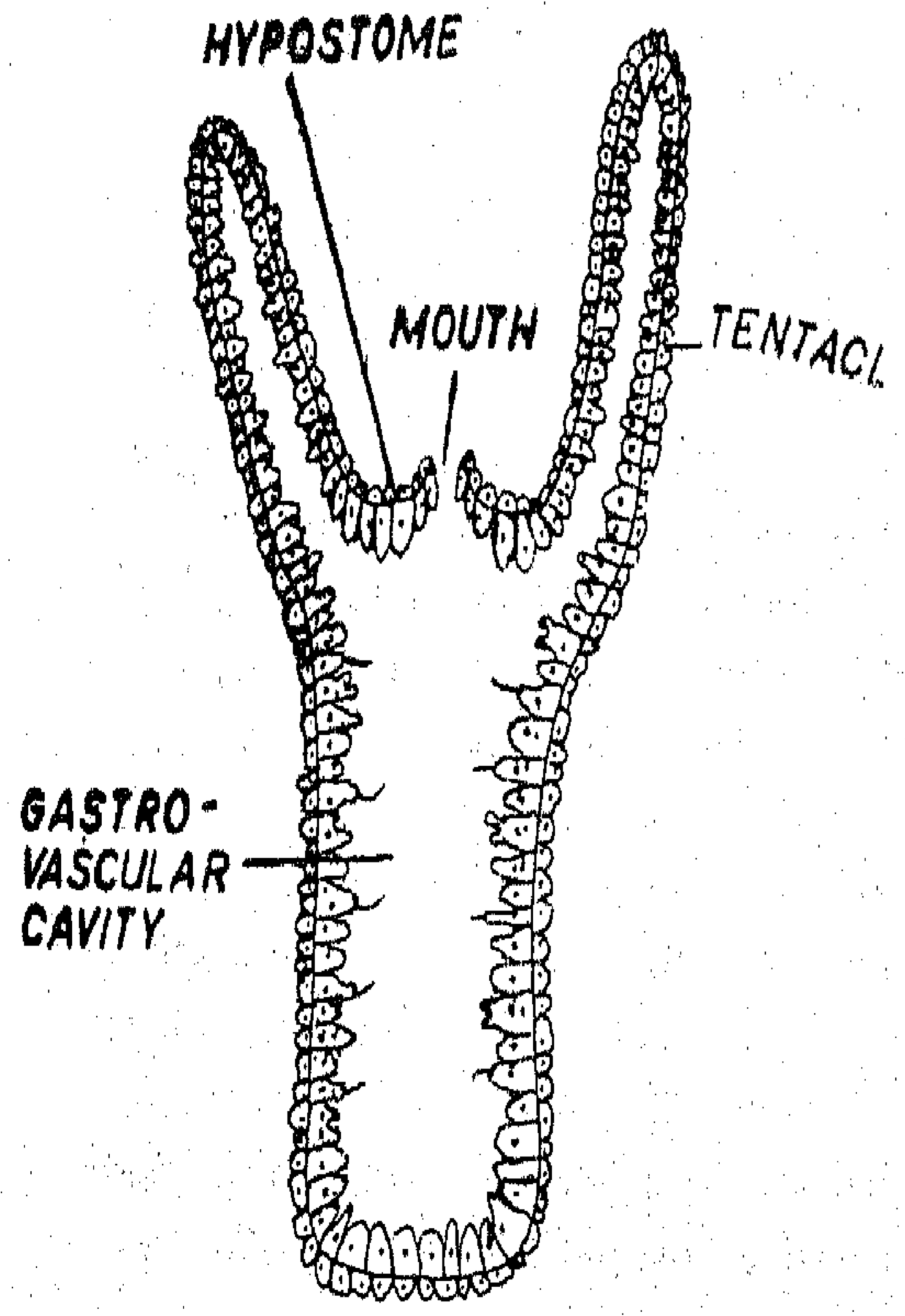


Fig. 105. *Hydra—Vertical Section*

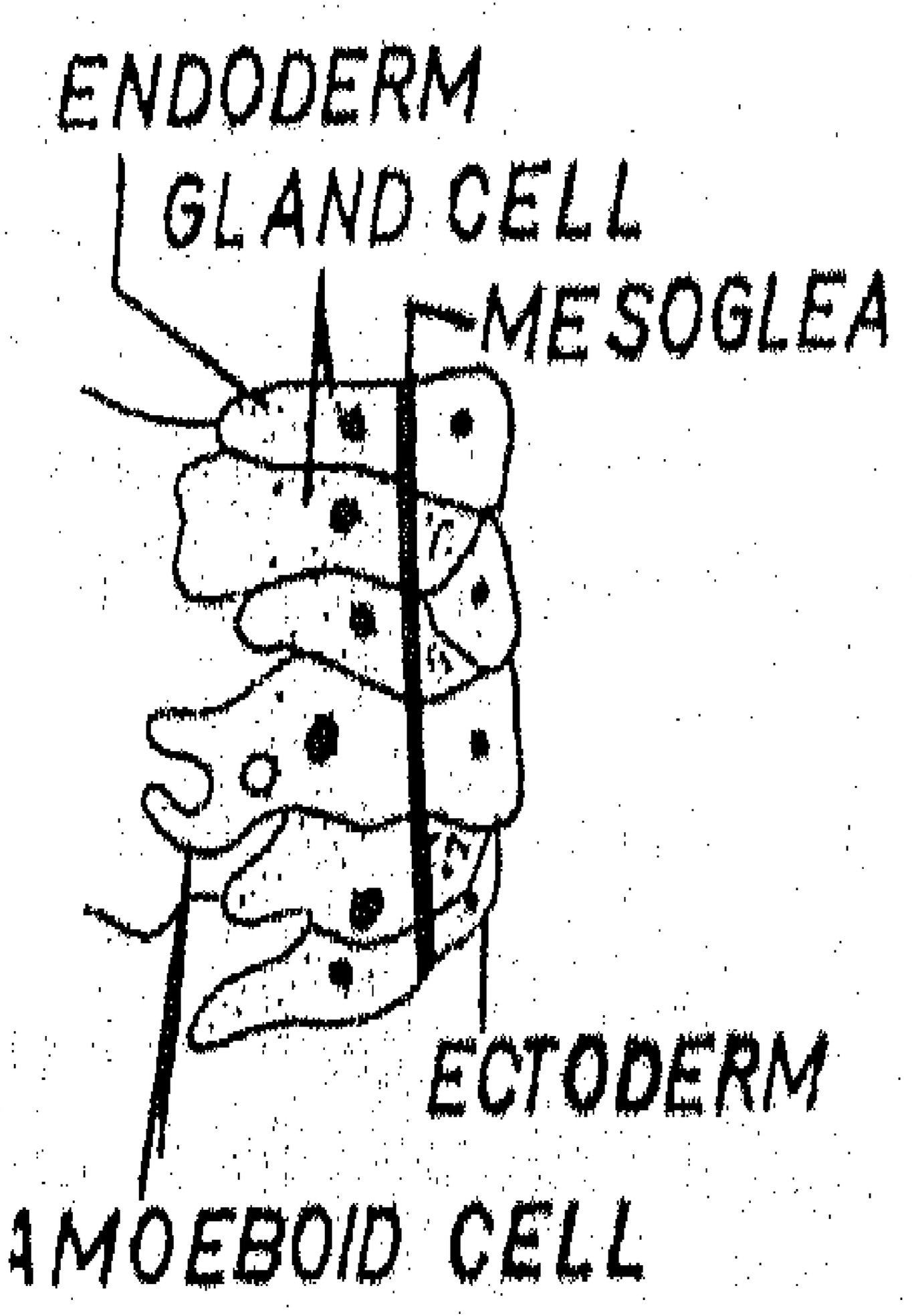


Fig. 106. *Body wall of Hydra (magnified)*

The hydra is carnivorous, and its food consists of minute microscopic animals such as water fleas, insect larvae, etc. (Fig. 104) Any small organism swimming near about paralysed by the action of the nematocysts. Then they are gathered by the swooping action of the tentacles and thrust into the mouth and passed into the coelenteron. There the prey is subjected to the action of the digestive juices secreted by the glandular cells of the endoderm. The digested food products are absorbed by the endoderm cells, from where they diffuse to each and every cell of the body. The undigested food matter is then forcibly ejected through the mouth by a sudden contraction of the body. There is no anus.

Since the digestion takes place inside a cavity lined by cells, *i.e.,* outside the cells, the process of digestion is called *extra cellular* digestion.

Apart from this type of digestion, intracellular digestion also takes place in the hydra, wherein the amoeboid nutritive cells of the endoderm ingest the food particles by extending their pseudopodia in the manner of an amoeba ; and digestion takes place within the cell itself. The digested food is then absorbed by the surrounding cytoplasm. The undigested residue is thrown into coelenteron, from where it is thrown to the exterior by way of the mouth.

The coelenteron is also called the gastro-vascular cavity, for it serves both in digestion and circulation of the digested food products to the different parts of the body. There is no special circulatory system.

Digestive System of Cockroach

The cockroach is an insect belonging to the phylum-Arthropoda. As in all other arthropodan animals, the *alimentary canal* (Fig. 107) is divisible into three regions : foregut, midgut and hindgut. This differentitation is due to the fact that both the forenut and the hindgut are lined with ectoderm, and hence are incapable of secreting any digestive enzymes Only the midgut is lined with endoderm cells, where digestion and absorption take place.

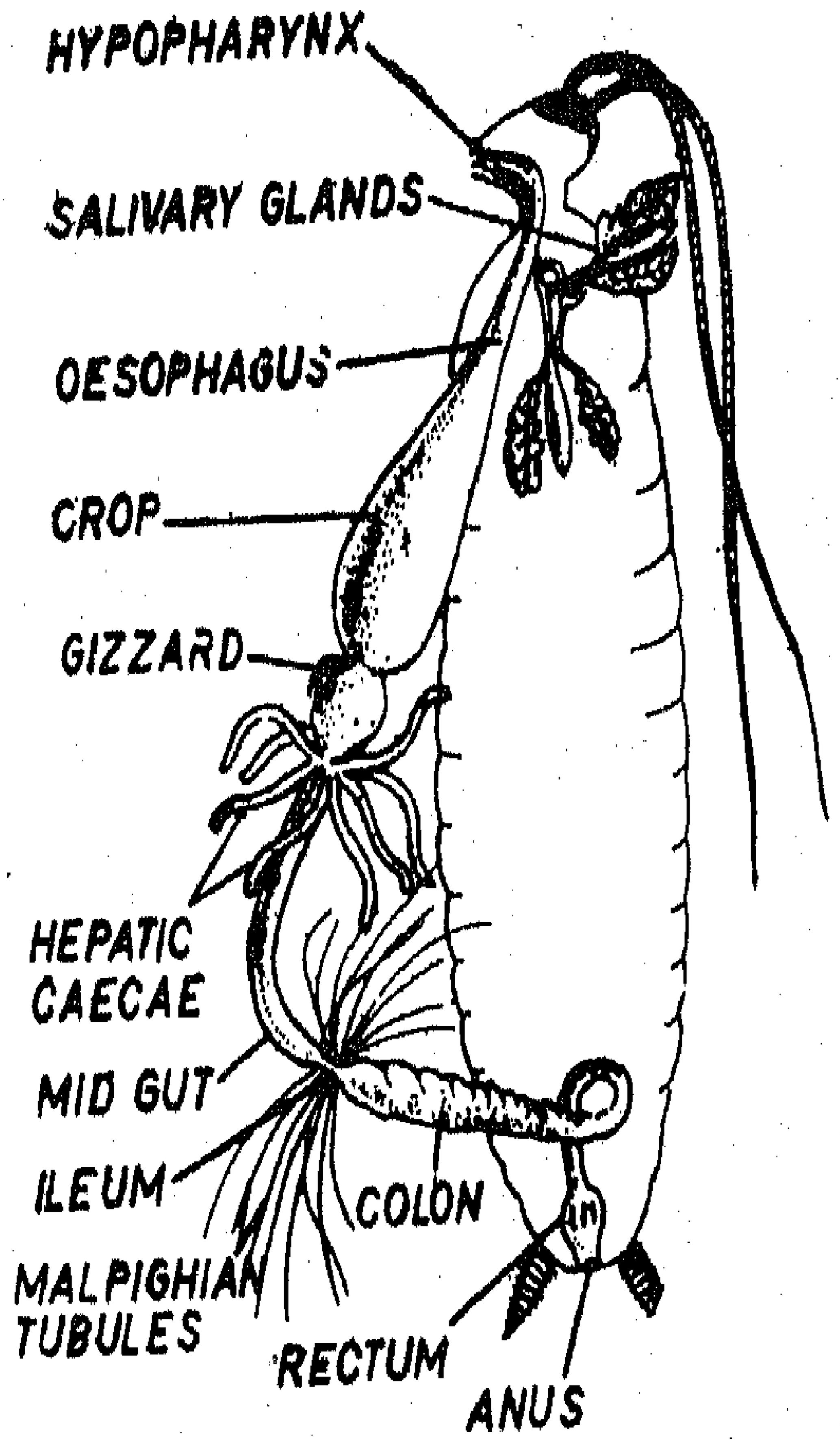


Fig 107. *Cockroach—Digestive System*

Foregut. It begins with the mouth. It is provided with certain mouth parts which help the animal in feeding. On either side of the mouth is a mandible or jaw (Fig. 108), which is provided with chitinous pointed teeth forming the cutting edges and which masticate the food material into small pieces. The mandibles are moved from side to side with the help of their muscles. In the buccal cavity is a chitinous rectangular tongue, the *hypopharynx*. A pair of salivary glands opens by a common duct at the base of the hypopharynx. The mouth leads into a short oesophagus, which expands posteriorly into a thin-walled bag-like structure, the *crop*, which forms a temporary storage chamber for the masticated food. This is followed by a thick-walled organ, the *gizzard*. The gizzard (Fig. 108) is muscular and its inner ectodermal chitinous lining is thickened to form six teeth. In the gizzard, the food is completely masticated into fine particles with the help of these chitinous teeth before it is allowed to pass into the next part of the alimentary canal. At the posterior end of the gizzard are present numerous fine bristles, which form a cushion and act as a strainer, preventing any coarse food particles from entering the midgut region.

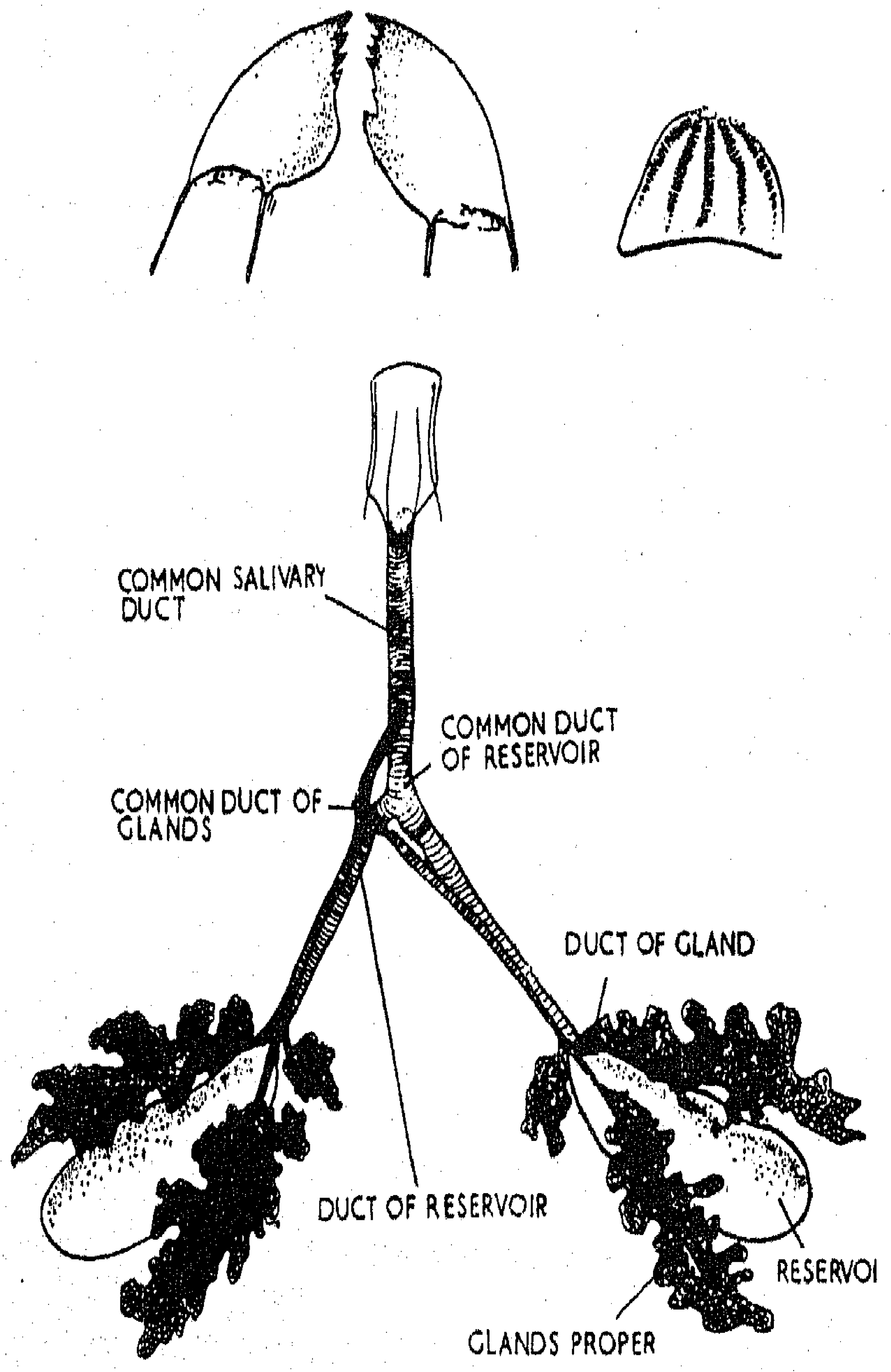


Fig. 108.

Midgut. The midgut or *mesenteron* is the only region of the alimentary canal which is lined with the endoderm, and hence is capable of digestion and absorption. Attached to its anterior end are present about 7 to 8 finger-shaped tubular structures, the *hepatic caeca*.

Hindgut. The hindgut has a very short and narrow portion, *ileum*, a long *colon* and an enlarged posterior portion, the *rectum*. The rectum opens to the outside by an anus, through which the faecal matter is disposed to the outside

At the junction of the midgut and the hindgut are found a large number of greenish yellow hair-like tubules arranged in groups ; they open into the hindgut. They are called *Malpighian tubules*, and are excretory in function.

There are two *digestive glands*.

Salivary glards. These are a pair of very much branched glands found one on either side of the oesophagus. (Fig. 108) Each gland is formed of two glandular lobes and a thin-walled bag-like *reservoir*. The ducts of the glandular lobes on their side unite to form a duct. Similarly, the two ducts of the reservoirs unite to form another duct. These two duct in turn unite to form a common salivary duct, which opens into the buccal cavity at the base of the hypopharynx.

These glands secrete the salivary juice, whose amylolytic enzyme acts on starch.

Hepatic Caeca. They are lined with endoderm, for they are the outgrowths of the midgut. At one end, they open into the midgut, and at their free ends they end blindly. They secrete a digestive juice which can digest proteins, fats and carbohydrates. Its secretion is regurgiated in the crop and brings about digestion of food substances in the crop, even though the crop by itself is incapable of any secretions and digestion. Secretions of the hepatic caeca and of the mesenteron can bring about complete digestion of food in the mesenteron. The digested food is then absorbed by the wall of the mesenteron and passed on to the surrounding *haemocoele* for distribution to the different tissues and cells of the body.

SUMMARY

1. Rabbit is a herbivorous animal which has a diet rich in cellulose.
2. The caecum in rabbit is enlarged. It contains bacteria which help in the digestion of cellulose.

3. Rat also has similar digestive system except that, the caecum is comparatively smaller and there is no gall bladder.
4. The ruminant animals like cow, sheep etc., have a four chambered stomach made up of (a) Rumen (b) Reticulum (c) Psaltarium and (d) Abomasum.
5. In birds the oesophagus is modified into a sac called the crop in which grains along with sand particles are stored.
6. During breeding season inner cells lining the crop degenerate to form the pigeon's milk which is fed to the young ones.
7. The stomach in birds is divided into proventriculus and gizzard, the former secreting gastric juice and the latter grinding the food.
8. The liver is bilobed and there is the absence of gall bladder in common pigeons.
9. Amoeba has no digestive system as such. The food is digested by enzymes secreted by cytoplasm. The digestion here is intracellular.
10. In hydra digestion is both extra and intracellular.
11. In cockroach the alimentary canal is differentiated into (a) Foregut (b) Midgut and (c) Hindgut.
12. Digestion and absorption takes place in midgut.
13. Malpighian tubules are excretory in function.
14. Hepatic caeca secrete enzymes which can digest carbohydrates, proteins and facts.

BIOLOGICAL WORDS

Caecum
Rumination
Psalterium
Abomasum
Crop
Proventriculus
Gizzard
Nematocyst
Malpighian tubules
Hepatic caeca
Rumen
Reticulum

QUESTIONS

1. Describe the alimentary canal of pigeon. State how the Protein and Carbohydrate are digested.
2. Describe the digestive system of cockroach and add a note on the physiology of digestion.
3. Write notes on:—

   (i) Ruminant stomach, (ii) Ingestion, (iii) Digestion in hydra and amoeba

   (iv) Caecum of rabbit.
4. Give one important function of the following:—

   (a) Caecum, (b) Reticulum of Ruminant stomach, (c) Crop of bir
   (d) Gizzard of cockroach, (e) Crop of cockroach, (f) Hepatic caeca
   (g) Malpighian tubules, (h) Pseudopodia of Amoeba, (i) Tentacles hydra.
5. Fill in the blanks:—

   (i) In hydra there is ————————as well as————.

   (ii) Malpighian tubules in cockroach are concerned with————

   (iii) During breeding season crop of pigeon produces————————

   (iv) The process by which the boluses are sent into the buccal cavity fror reticulum is known as————————

Circulation

9

Multicellular organisms are surrounded by an external environment—air or water; but their cells live in an internal fluid environment. The functions of these organisms are so regulated as to maintain this internal fluid environment in a stable condition. In some of the lower multicellular organisms, however, where there is no circulating fluid and where their tissuses are in direct contact with the external aqueous environment, a direct metabolic exchange with the surrounding medium is possible.

In higher animals, the internal circulatory fluid moves through a system of closed tubes or vessels. This system of vessels is known as the *Circulatory System.* In the vertebrates, the circulating fluids are of two kinds : (1) Blood and (2) Lymph.

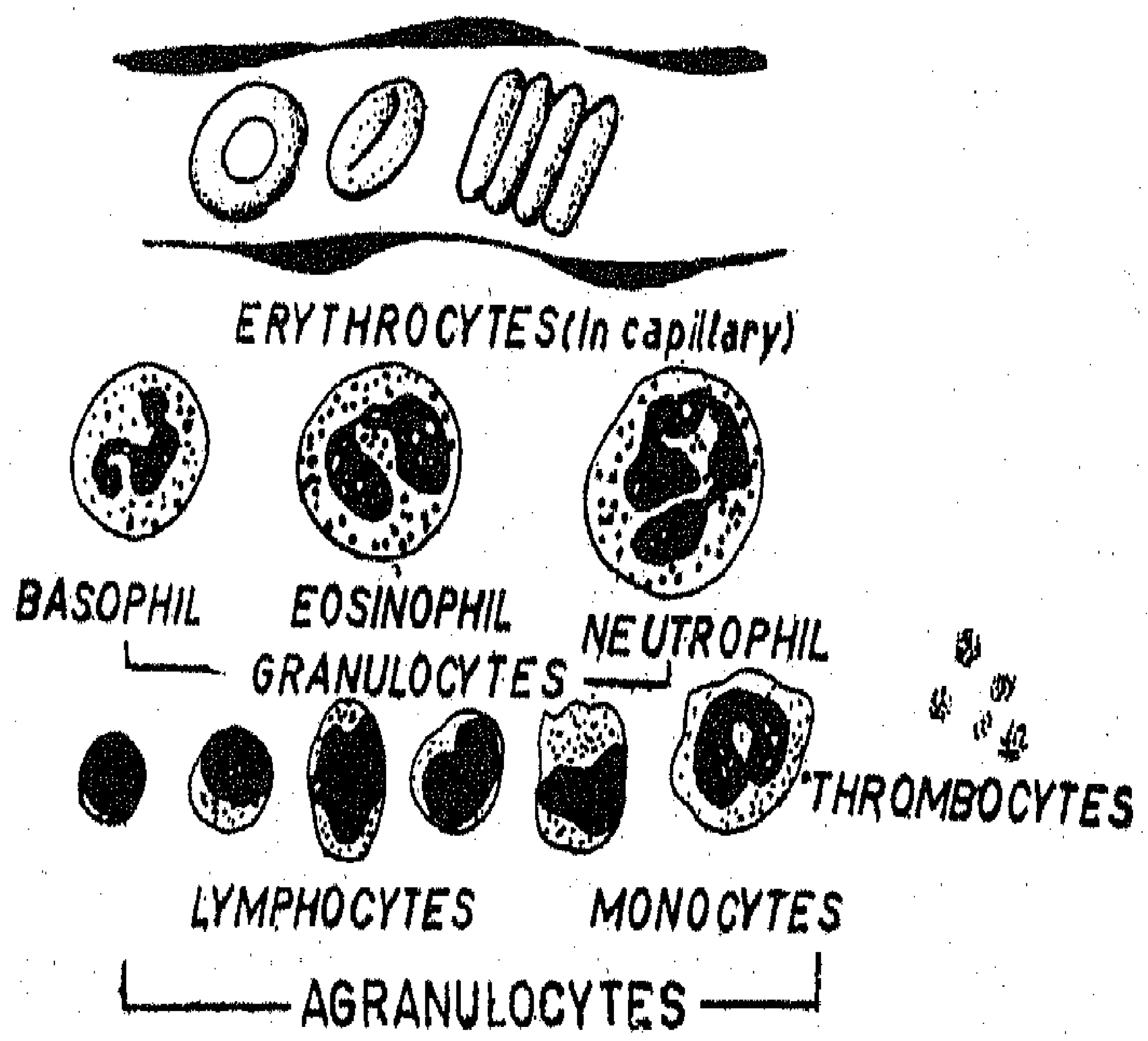


Fig. 109. *Human—Blood corpuscles*

A system of vessels through which the blood circulates is termed as the *Blood Vascular System* and the other system through which the lymph circulates is known as the *Lymphatic System.*

BLOOD

Blood is a connective tissue. (Fig. 115). It is a red, opaque, viscid fluid which is alkaline in reaction. It consists of a yellow fluid, the *plasma*, in which are suspended a number of free cells—the *corpuscles*. (Fig. 109). These corpuscles are of three kinds: (1) Red Blood Corpuscles (R. B. C.) or *Erythrocytes*; (2) White Blood Corpuscles (W. B. C.) or *Leucocytes*; and (3) Platelets or *Thrombocytes*.

Red Blood Corpuscles (R. B. C.). In man and other mammals, these corpuscles are biconcave, circular disc-like cell. Due to biconcavity, they appear as dumb bell shaped cells. The most peculiar feature of these cells is the absence of the nucleus (except in camel), and hence they are known as enucleated cells. The cytoplasm contains a large amount of respiratory pigment, the haemoglobin. The pigment is made of iron (haem) and a protein (globin). This imparts the red colour to the blood. It has a great affinity for oxygen, with which it combines readily to form an unstable compound known as oxyhaemoglobin. Due to its unstable nature, it can readily dissociate, giving off its oxygen to the tissues of the body, thus reducing itself to the original state, the haemoglobin. The cells are thus oxygen carriers. The erythrocytes are continuously manufactured in the bone marrow, liver and, to some extent, in the spleen. When they are worn out and are of no use to the body, they are destroyed in the spleen. (The haemoglobin of such cells is converted into bile pigments in the liver). However, there is no evidence that normal erythrocytes undergo any destruction in the spleen.

White Blood Corpuscles (W. B. C.). They are present both in the blood and the lymph and, in small numbers, in the tissues and tissue fluids as well. They are fewer than the red blood cells, about 5000 to 7000 per c. m. of blood as against 5 million red blood cells in the same volume. They are colourless because of lack of any respiratory pigment. They have no definite shape, for they exhibit amoeboid movement. They are nucleated and are of different sizes and kinds. The shape of the nucleus varies, and may be spherical or deeply lobed, or kindey-shaped.

Leucocytes are divided into *granulocytes and agranulocytes*. The granulocytes have certain granules in the cytoplasm, which stain differently with different types of stains. According to this differential affinity, the granulocytes are classified as *eosinophils* (staining with acidic stains), *basophils* (staining with basic stains) and *neutrophils* (staining with neutral stains). The granulocytes are also called *plymorphonuclear leucocytes*, for the nucleus is constricted into a number of lobes.

The agranulocytes are without any granules in the cytoplasm or, if present, they are very fine. The agranulocytes are of two kinds: (a) the *Lymphocytes* are small spherical cells, containing a relatively large round nucleus, while (b) the *Monocytes* are the largest leucocytes. The nucleus is horse-shoe-shaped, or may be rounded or oval.

The leucocytes can engulf, ingest, and digest, in the manner of the amoeba, any foreign bodies or disease germs like bacteria that enter into the body. The process of engulfing and eating up of the foreign bodies is known as *phagocytosis*, and the leucocytes are referred to as *phagocytes*. Whenever foreign organisms like bacteria enter the body, the phagocytes reach there in large numbers and ingest and destroy them, thus preventing the disease from spreading. Thus, they act as bodyguards. In this fight with foreign organisms, some of them also get killed. They also act as *scavengers* by ingesting the dead tissue cells in the body. They can migrate through the capillary walls into the intercellular spaces in the tissues and back into the blood stream *i. e.* they can become extra-vascular.

The leucocytes are formed in the bone marrow and lymph nodes, and also in liver and spleen. The worn out w. b. c. s. are destroyed in the spleen.

Platelets or thrombocytes. They are the smallest cells in the blood. They are oval and non-nucleated. They are very delicate, and they easily get disintegrated or destroyed on contact with any rough surface. When a tissue is wounded, the platelets get destroyed, and a substance known as *thromboplastin* is liberated from them. This is a blood-clotting factor, which brings about the clotting or coagulation of blood. The platelets are formed in the bone marrow.

Plasma. The plasma is a clear, transparent yellow liquid portion of the blood, containing about 90% water and 10% of other solids like the proteins, certain important salts, the nutritive materials like glucose, amino-acids and fats. There are also present certain *hormones*, which are the essential secretions of the ductless or *endocrine* glands. Present in small quantities are also the waste materials of metabolism, such as urea, uric acid, CO_2, etc. The important salts present are the chlorides, carbonates, bicarbonates, phosphates and sulphates of sodium, calcium, potassium, magnesium and iron.

The total amount of proteins is about 7% to 8%. The plasma contains the following proteins: (1) Serum albumin and (b) serum globulin. Fibrinogen is one of the important globulins dissolved in the plasma and is usually considered distinct from the above group of proteins because it possesses the remarkable property of becoming insoluble under certain conditions. It changes into fibrin and brings about the coagulation of the blood.

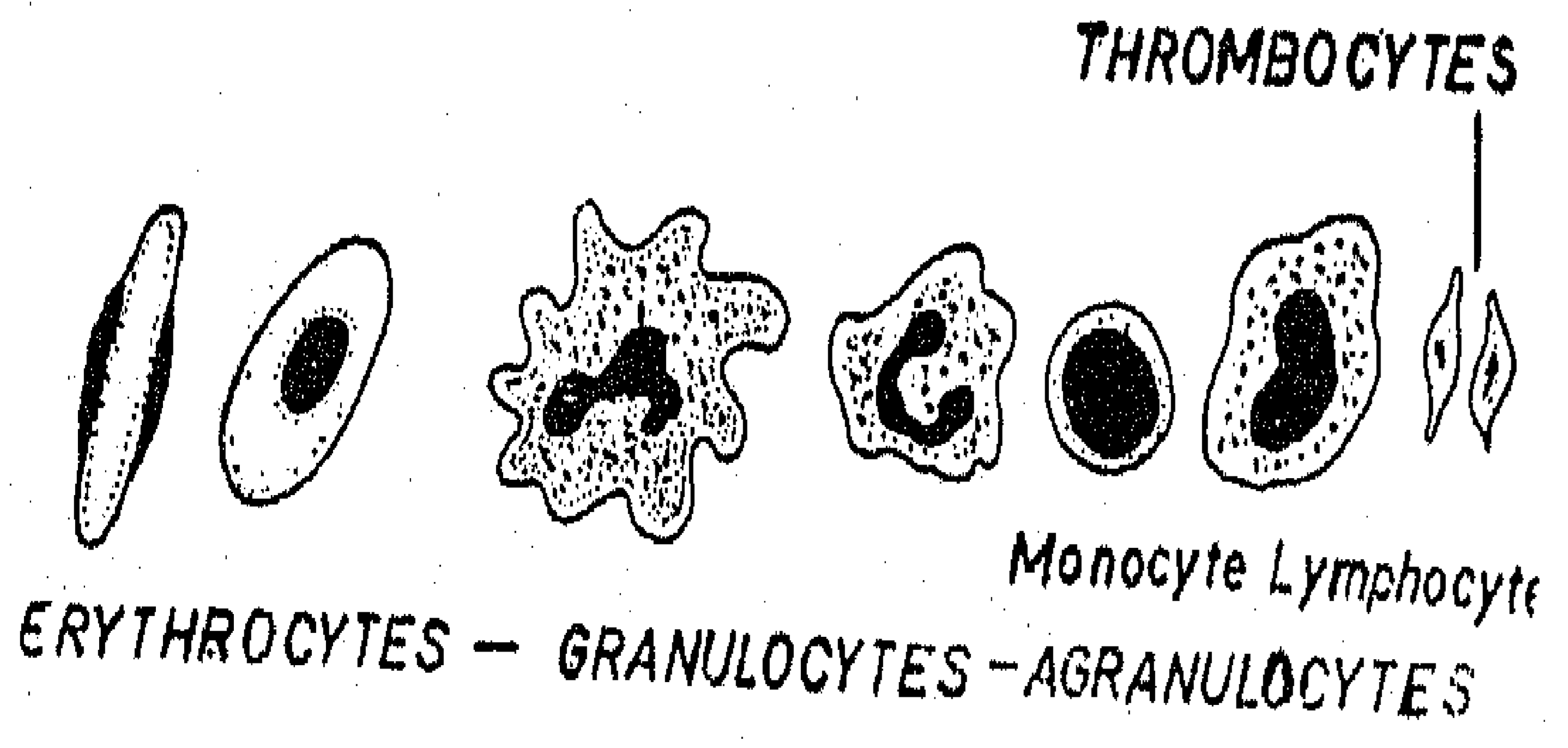


Fig. 110. *Frog—Blood corpuscles*

The blood of frogs (Fig. 110) (as in fishes, other amphibians, reptiles and birds) differs from the mammalian blood in the structure of its red blood cells. The r.b.c.s. in these vertebrates are oval or elliptical, nucleated and biconvex. The cells are larger than those in mammals. The thrombocytes are mostly spindle-shaped and nucleated.

Function of the Blood

The blood is an important medium of transport within the body. Due to it, various vital functions of the body are carried out without any hindrance.

Some important functions of blood are:

(a) **Nutrition.** It carries digested foodstuffs such as glucose, amino-acids, fats, etc., absorbed from the intestine to different cells of the body.

(b) **Respiration.** It carries oxygen from the lungs to the tissues.

(c) **Excretion.** It carries the waste products of cellular metabolism such as urea, uric acid, creatinin to the excretory organs, the kidneys, from where they are eliminated.

(d) **Temperature regulation.** The heat, which is generated by oxidation in the body, is evenly distributed to the different parts of the body. Excess of heat is brought to the lungs or to the surface of the body so that it may be eliminated to the outside. Thus it helps in maintaining a constant temperature.

(e) **Defence.** The phagocytic leucocytes engulf and destroy foreign organisms like bacteria that invade the body. The blood also contains antitoxins and antibodies which counteract poisons or toxins that are formed in the body due to metabolic activities or due to the presence of the foreign organisms in the body.

(f) The tissues are constantly bathed in water without which the metabolic chemical reactions would not occur.

(g) It also transports hormones, *i.e.*, secretions of endocrine glands, to different organs of the body. These secretions are essential for the normal functioning of the body.

(h) The clotting property of the blood prevents wastage of nutrients from the body by plugging the wounds.

Coagulation or clotting mechanism of Blood.

The coagulation of the blood or clotting is a process of formation of a jelly like clot which plugs the wound and prevents the further loss of blood.

The mechanism of the clotting of vertebrate blood is a complicated process. Several steps are involved in clotting. During clotting, the blood protein, the *fibrinogen*, which is in a soluble state, is precipitated in the form of a dense meshwork of fine threads of insoluble *fibrin*. In the meshes of these threads, the blood corpuscles become entangled, thus forming a clot. This conversion of fibrinogen into fibrin takes place because of the action of an enzyme, the *thrombin*. Thrombin is not present in an active form, but occurs in an inactive state ealled *prothrombin*. *Thromboplastin* is another substance present in the tissue cells platelets and quite possibly in leucocytes. But it is not present in a free state. Only when there is a wound and the blood is oozing, the thromboplastin is formed from the disintegrating thrombocytes, injured tissue cells and also from the leucocytes. This thromboplastin acts upon the inactive *prothrombin* in the presence of *calcium*, which is also present in the blood and converts it into *thrombin*. Thrombin, in turn, acts upon the fibrinogen of the blood and converts it into in soluble fibrin. Blood corpuscles get entangled in the fibrin meshes and form a clot. The yellow liquid, which is left out after the clot is formed, is the *serum*. It is similar to plasma, but without fibrinogen.

Blood Cloting:—

(1) Thromboplastin + Prothrombin + Calcium ⟶ Thrombin.

(2) Thrombin + Fibrinogen ⟶ Fibrin.

(3) Network of Fibrin + Blood cells ⟶ Clot.

In normal healthy blood vessels, the blood is prevented from clotting, since there is not sufficient free thromboplastin or thrombin. Even when a little thrombin is formed, it is neutralised by an anti-thrombin called *heparin*, which is present in the blood, and the intra-vascular clotting cannot take place.

Lymph and Lymphatic System

Lymph. The lymph is a clear, alkaline, viscid fluid. It is similar in composition to the blood plasma, but only diluted so far as its protein constituents are concerned. The proteins are fibrinogen, serum globulin and serum albumin. The salts are similar to those of the blood plasma. It also has nutritive substances and oxygen. The lymph does not contain red blood cells;* but white blood cells, particularly the lymphocytes, are present in a large number.

When the blood is supplied to the tissues and the cells through capillaries, it filters out of the capillary lining into intercellular spaces carrying all the absorbed food material and oxygen to the cells. Only a part of tissue fluid goes back to the blood stream by way of venous capillaries. The rest of the tissue fluid is collected by a network of fine vessels called *lymph capillaries*, which join and form bigger lymphatics or lymph vessels. The tissue fluid, after it has filtered into the lymph capillaries, is called th lymph.

The lymphatic vessels are thin-walled. They unite to form only two trunks, of which the left one is larger and is known as the thoracic duct. They open into right and left subclavian veins respectively, which in turn open into the right auricle through the precaval. Thus the tissue fluid comes back into circulation as lymph. The lymph capillaries of the intestine are called *lacteals*.

Lymph nodules or glands occur along the course of lymphatics. Lymph nodes perform two functions. One of them is the production of lymphocytes; the second function is to intercept foreign bodies by filtration and phagocytosis.

The spleen is a large lymph node. The worn out red blood corpuscles are destroyed in the spleen; and the white cells (lymphocytes) are produced and also destroyed here.

Human Heart.

The heart is responsible for the force necessary to make tthe blood circulate in the body. It is also an organ which collects the blood from all parts of the body and also distributes it back to the body.

Structure of the heart. It is a hollow organ with muscular walls, made up of a special type of muscles called cardiac muscles. (Fig. 111). It is conical in shape and about the size of a man's fist. It is present midventrally in a space found between the two lungs in the thoracic cavity. It is covered by a double-layered, thin-walled sac, the *pericardium*. It is broad at the base and pointed at the apex.

The heart (Fig.112) is mainly divided into two parts, the auricle and the ventricle. Each of them is further divided into right and left chambers by a vertical partition. The upper right and left thin-walled *auricles* are the chambers which receive the blood from the different parts of the body. The lower two *ventricles* are thick-walled and are the distributing chambers.

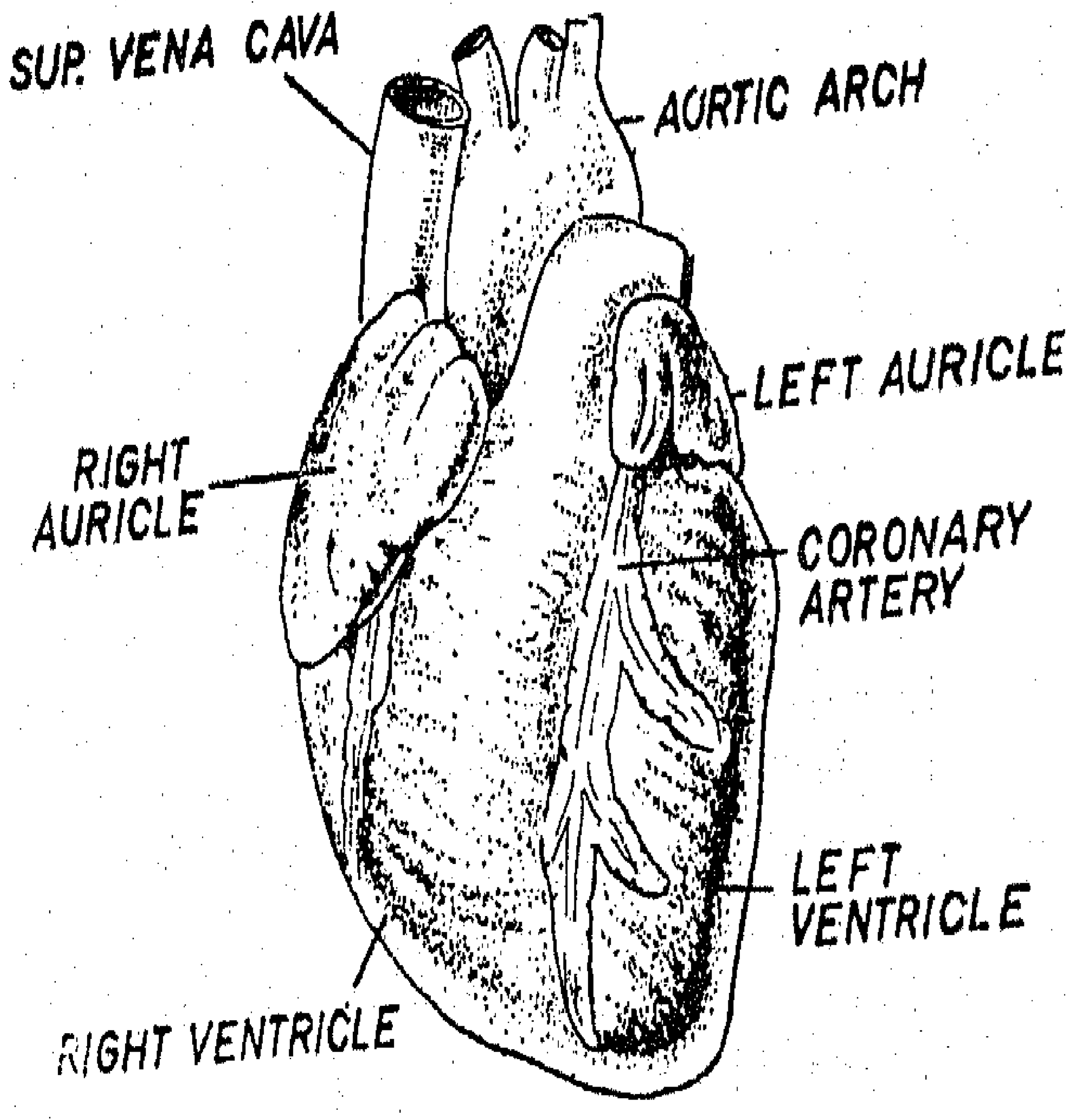


Fig. 111. *Human Heart—External view*

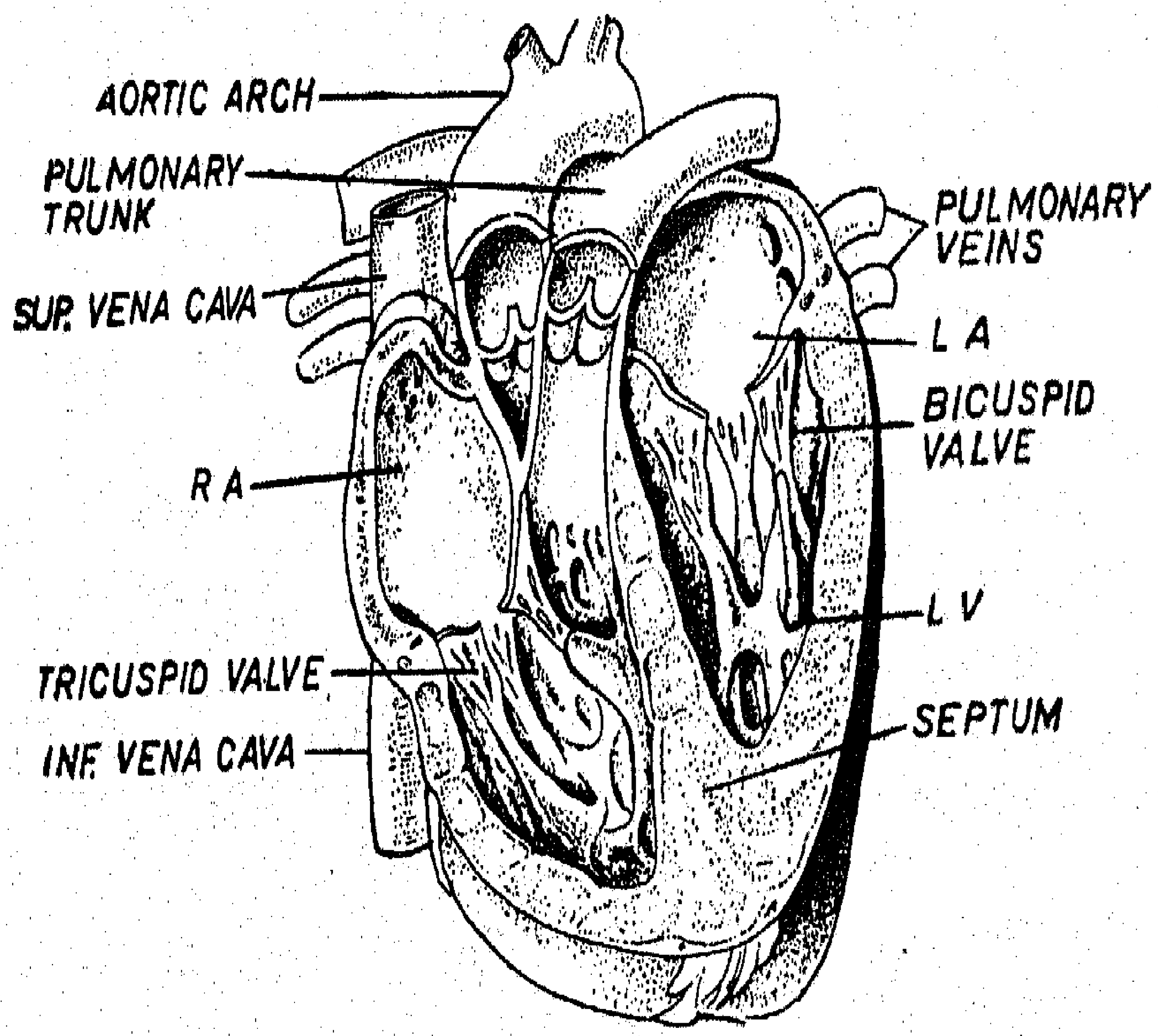


Fig. 112. *Human Heart—Vertical Section*

The vertical partition separating the two auricles is called *inter-auricular septum* and the one which divides the ventricle into two is the *inter-ventricular septum*. Each auricle communicates with its corresponding ventricle down below by an aperture, the *auriculo-ventricular aperture*. Each opening is guarded by a valve called the *auriculo ventricular valve*.. The right auriculo-ventricular valve is known as *tricuspid* valve and the left one is called the *bicuspid* valve or the *mitral* valve. The tricuspid has 3 membranous, cup-shaped flaps, while the bicuspid has 2 such flaps. These flaps are attached to the musculature of the ventricle by means of tendinous cords, the *chordae tendinae*, which prevent them from folding back into the auricles during the contraction of the ventricles. These valves allow the blood to move only in one direction, *i.e.*, from auricles to ventricles, but not in the opposite direction.

The venous blood collected from the different parts of the body is ultimately brought back to the heart by means of two great vens. One of them the *Superior Vena Cava or Precaval* vein, open into the right auricle obliquely from above. The other is the Inferior Vena Cava or Postcaval vein, which opens into the right auricle from the posterior end. The latter opening is guarded by 3 semi-lunar valves.

The left auricle is slightly smaller than the right one. The pulmonary veins, bringing oxygenated blood from the lungs, open into it.

Internally, the ventricles are provided with muscular ridges. The right ventricle opens into the pulmonary trunk, which carries deoxygenated or impure blood to the two lungs for oxygenation. The opening into the pulmonary trunk is guarded by 3 semi-lunar *pulmonary valves*. These prevent backflow of blood from the pulmonary trunk to the ventricle.

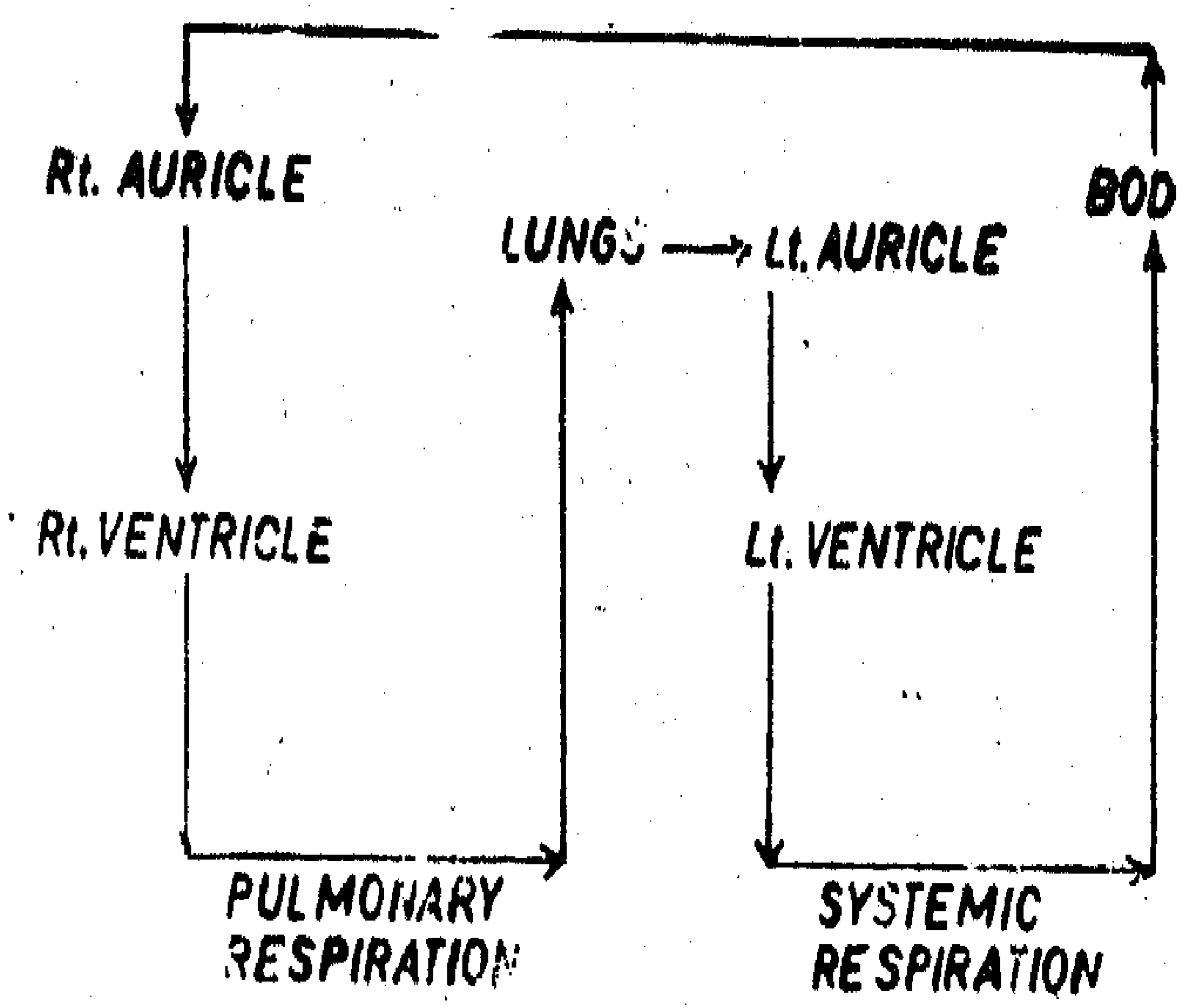
The left ventricle is larger and more muscular than the right, since it has to pump the blood to the entire body. It opens into the great arterial trunk, the *aorta*, which supplies the blood, through its branches to all the parts of the body. Its opening also has 3 semi-lunar valves, allowing the blood to move only in the forward direction.

Since the heart is completely partitioned, the oxygenated blood and the deoxygenated blood are not allowed to mix.

Mechanism of the Heart. The heart is the pumping organ in blood circulation. There is a constant rhythmic contraction and relaxation of the heart, which keeps the blood moving. The human heart beats about 72 times per minute. The result of the heart beat is to pump the blood into the arteries. It is felt as pulse on the arteries. The contraction of the heart is called *Systole*, and its relaxation is known as *Diastole*. During the auricular diastole, the right auricle receives the deoxygenated or venous blood from the body through the pre and post-cavals. The left auricle receives the oxygenated blood from the lungs through the pulmonary veins. Now both the auricles contract simultaneously, driving the blood from the right and the left auricles into the right and the left ventricles respectively, through the right and the left auriculo-ventricular openings. When the right and the left ventricles are full with deoxygenated and oxygenated blood respectively, both the ventricles contract simultaneously. The systolic pressure of the ventricles closes up the tricuspid and bicuspid valves. The blood forces open the semi-lunar valves at the bases of the pulmonary and the aortic trunk. Thus the deoxygenated blood from the right ventricle is driven on to the lungs for oxygenation, and the oxygenated blood from the left ventricle is distributed to the different parts of the body.

It is obvious, therefore, that there are two clear-cut circuits through which the blood circulates. Through one circuit, the blood from the left side of the heart, which is the oxygenated blood, is sent to all parts of the body and back again to the right side of the heart. This is called *systemic circulation*. The other circuit takes place from the right side of the heart, from where the deoxygenated blood is taken to the lungs for oxygenation and back again to the left side of the heart. This is known as *pulmonary circulation*. This type of circulation is also calld *double circulation*, which is found in all the vertebrates, except fishes.

In man and other vertebrates, as well as in some invertebrates, the blood is always flowing within the vessels and capillaries. This type of circulation is called *closed circulation*. In some invertebrates, particularly arthropods like lobster, cockroach, etc., the blood is not entirely confined to the blood vessels, but flows through the small open spaces called *sinuses* found in between organs. This type of circulation is called *open circulation*.



Blood Vessels. The blood vessels which carry the blood towards the heart are called *veins* and those vessels which carry it away from the heart are called the *arteries*. The arteries have thicker muscular walls, and hence do not collapse when the blood is completely drained out from them. They are without any valves.

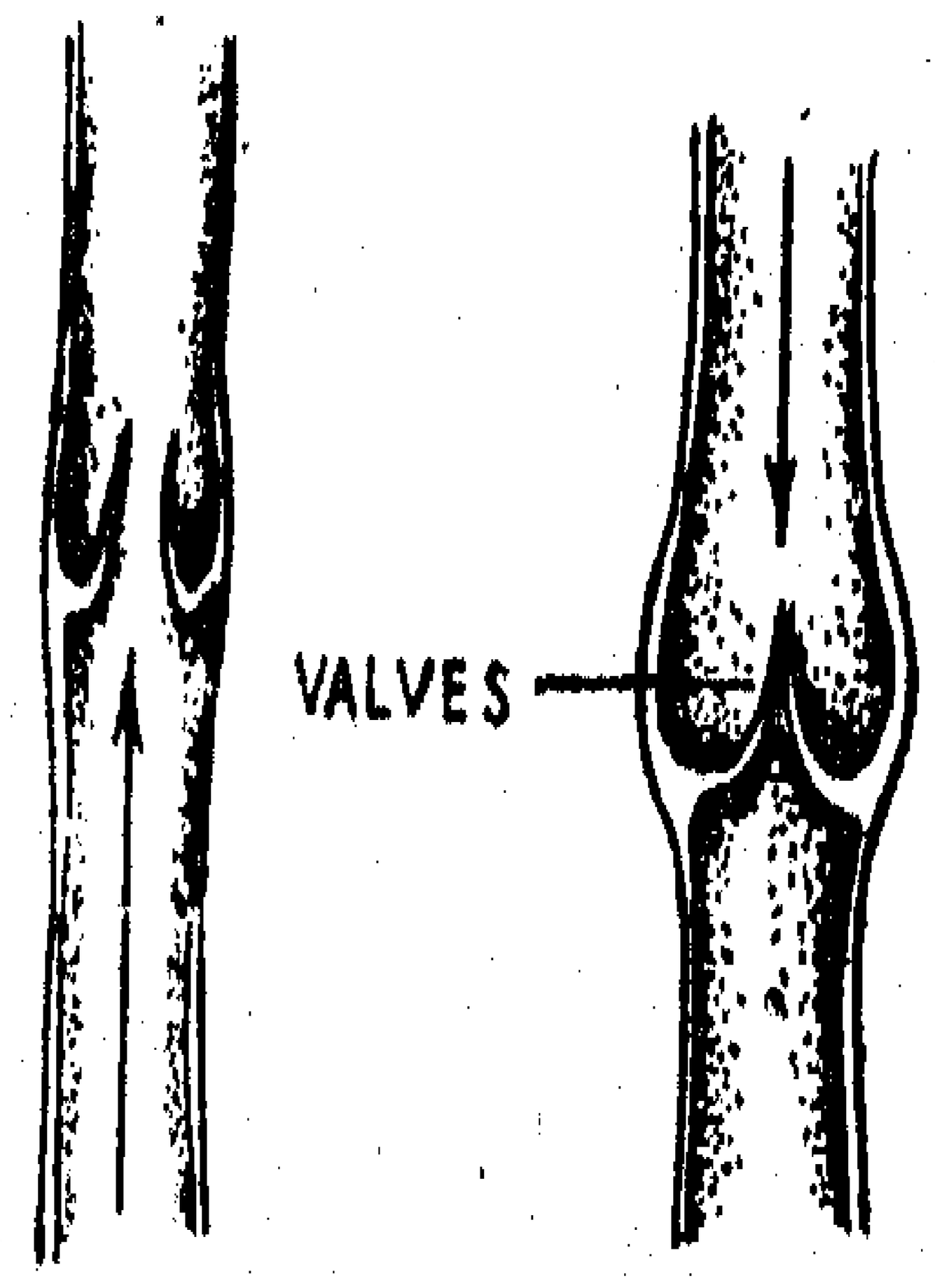


Fig. 113. *Valves in veiens*

Veins have thinner walls, and have a bigger bore inside. In the absence of any blood inside them, they collapse. They are usually provided with paired valves (Fig. 113) of pocket-like flaps, which allow the blood to flow only in the direction of the heart *i.e.*, one way only.

The arteries go on branching into smaller and smaller branches called *arterioles* which, on further ramification, form minute blood vessels called *capillaries*. These capillaries are extremely thin-walled.

These capillaries unite and reunite to form small collecting vessels or *venules* which, after joining together, form larger veins. Thus, between the arterial and the venous blood vessels there is a system of capillary network. In this network, an exchange of gases, namely, O_2 brought by the arterial blood and CO_2 formed in the tissues, takes place. In this network, another exchange

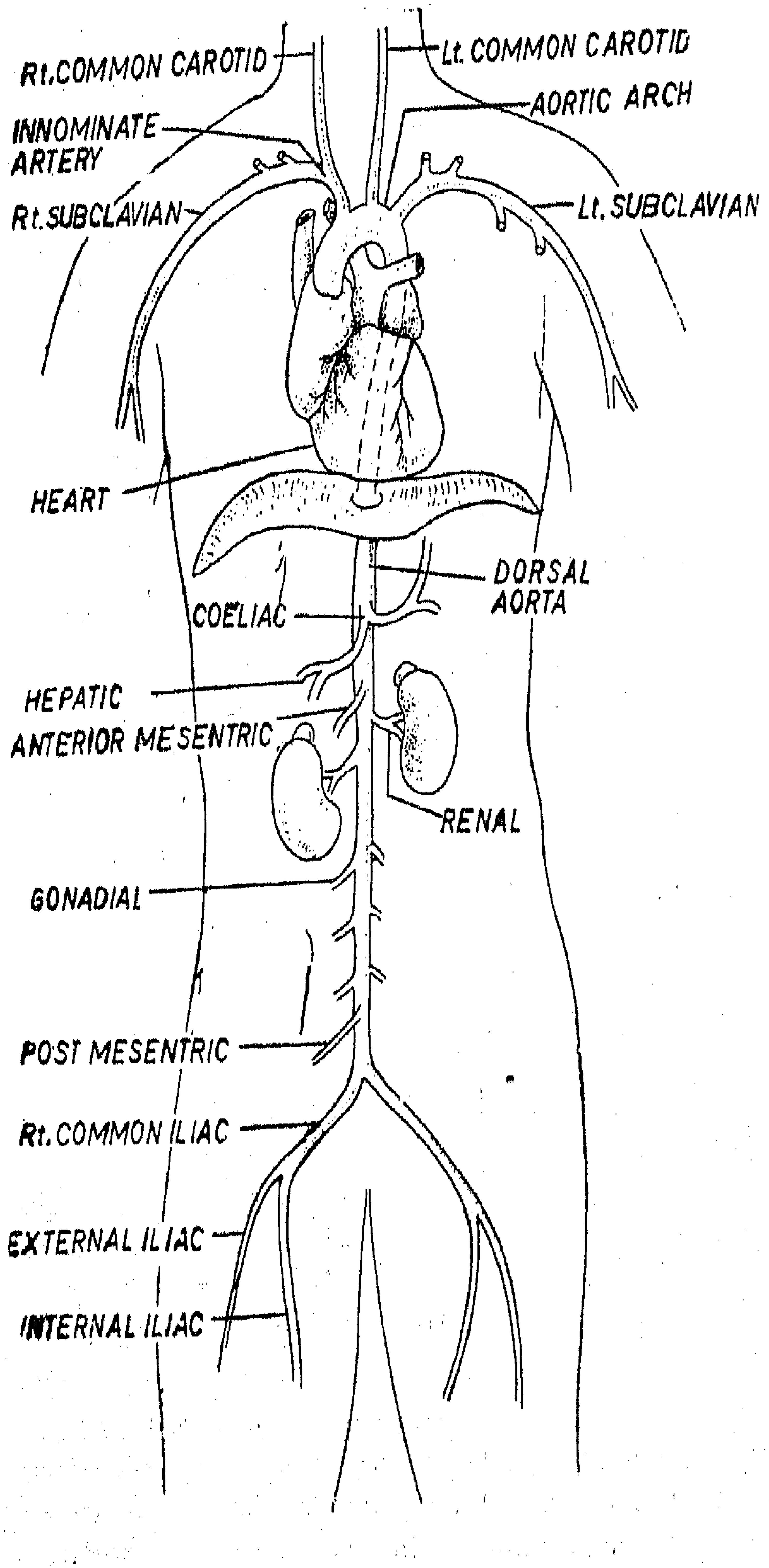


Fig. 114. *Human—Arterial system*

also takes place between the food products brought by the arterial blood and the waste products of metabolism formed in the tissues. Thus, when these are collected from the tissues, the venous blood becomes impure by reason of the presence of CO_2 and waste materials.

The Circulatory System is divided into (1) Arterial System and (2) Venous System.

Arterial System. It is a system of blood vessels which carry the blood from the heart (*i. e.*, from the ventricles) to the different parts of the body. (Fig. 114).

The main arterial trunk, which is given out from the left ventricle, is the *aorta* or aortic trunk. After coming out of the heart, it travels upwards, then turns to the left as the aortic arch and travels downwards into the thoracic cavity and the abdominal cavity, running parallel to the vertebral column as the *dorsal aorta.*

Anteriorly, the aorta gives off blood vessels to the head, the shoulder region and the arms.

The descending aorta gives off a number of branches to the liver (hepatic artery), stomach (gastric artery), small intestine, (superior mesenteric), and kidney (renal artery); and finally it divides into 2 common iliac arteries, which go into the legs.

The *pulmonary trunk* is given off from the right ventricle. Immediately on coming out of the heart, it divides into right and left pulmonary arteries, going to the right and left lungs. These take the deoxygenated blood to the lungs for oxygenation.

The heart itself is supplied with oxygenated blood by a pair of coronary arteries arising from the aorta where it emerges from the ventricle

Venous System. The blood is collected from the different parts of the body by means of venous branches, ultimately forming the following main veins (Fig. 115):

(1) The **Superior Vena Cava** brings the blood from head, neck, shoulder and arms. This opens into the right auricle at its upper end.

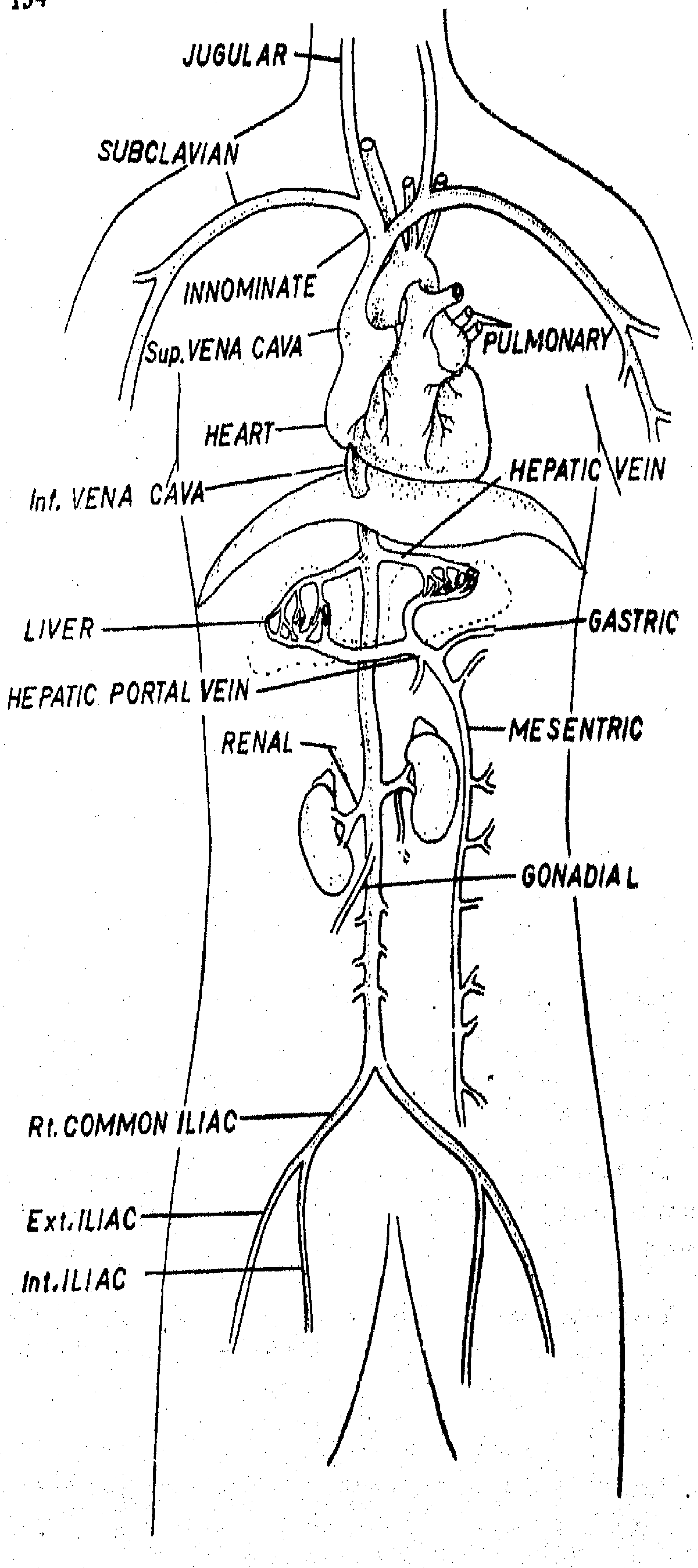


Fig. 115. *Human—Venous system*

(2) The **Inferior Vena Cava** receives the blood from the different visceral organs like the kidney, liver, from the trunk regions and also from the legs. This vein opens at the lower end of the right auricle.

(3) The **Pulmonary veins** bring oxygenated blood from the lungs to the left auricle.

(4) **Hepatic Portal System.** Apart from the main veins, there is a system of veins collecting the blood from different parts of the alimentary canal, such as the stomach, intestine, pancreas, liver, etc. These unite and form a hepatic portal vein, which breaks open into capillaries in the liver instead of directly opening into the post-caval or the heart. Normally, the veins are formed by the union of capillaries, and venules. If a vein thus formed breaks up again into capillaries, it is called a *portal vein.* The hepatic portal vein breaks up into capillaries in the liver tissues. In the liver, the excess of glucose is taken up and converted into insoluble glycogen and stored in the liver cells. The capillaries of the hepatic artery and those of the hepatic portal vein unite to form the hepatic veins, which

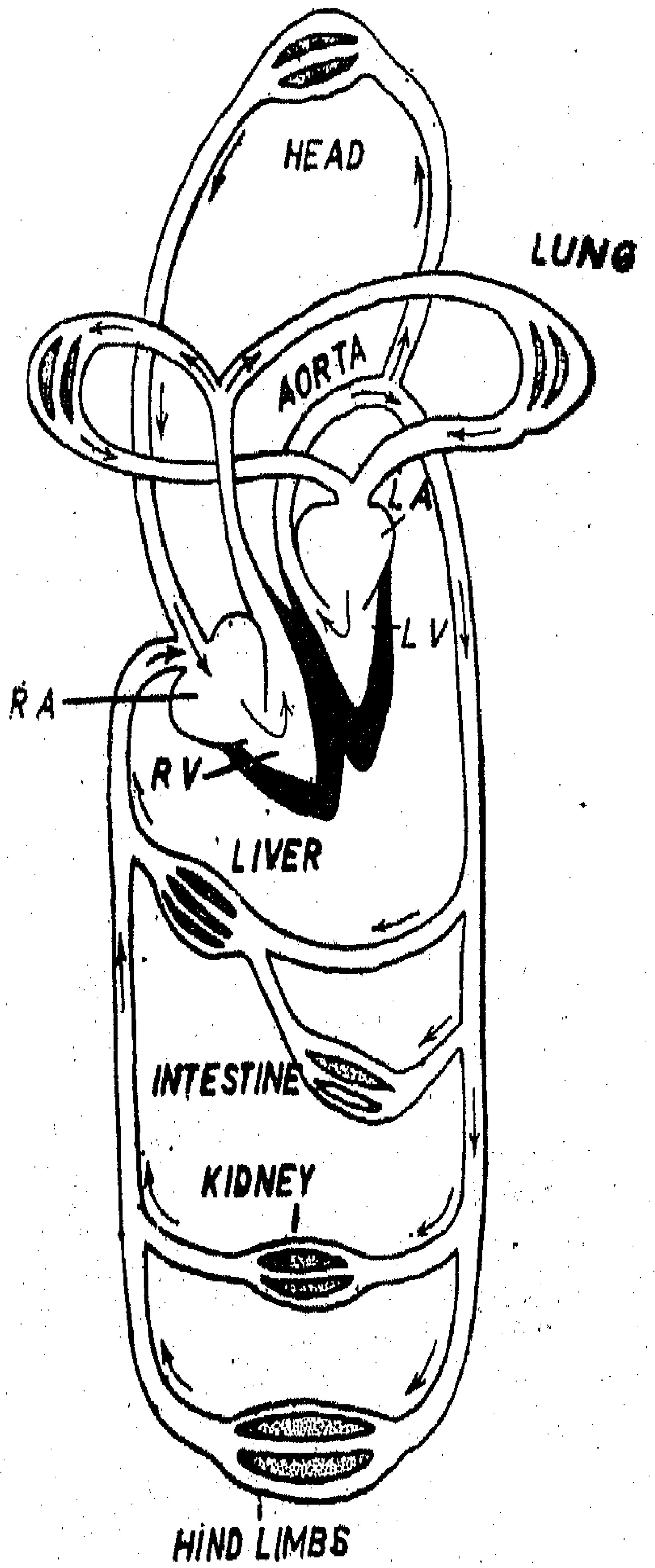


Fig. 116. *Human Circulation (Diagrammatic)*

open into the inferior vena cava. This portal vein along, with its tributaries constitutes the *hepatic portal system.*

The purpose of this branching of a portal system into an nintermediate organ, instead of opening directly into the heart seems to increase absorption of certain materials from the blood since the capillaries expose a greater surface area for absorption. Therefore, the portal vein, instead of just passing through an organ, breaks into a network of capillaries. Since the intermediate organ here is the liver, this portal system is referred to as the hepatic portal system.

The hepatic portal system is present in all the vertebrates. The renal portal system (where the vein bringing blood from the limbs enters the kidney and breaks into capillaries) is present in fishes, amphibians and reptiles, but not in Aves and Mammals.

Circulation in Frog

Heart of frog. The heart is a triangular muscular organ enclosed by a pericardium. (Fig. 11.7). It consists of two thin-walled auricles, the right and the left, and a single thick-walled ventricle. On the dorsal aspect of the heart is a thin-walled triangular sac, the *sinus venosus*, opening into the right auricle. The sinus venosus receives the deoxygenated blood by way of two pre-cavals and one post-caval. The pre-cavals, as in man, bring the

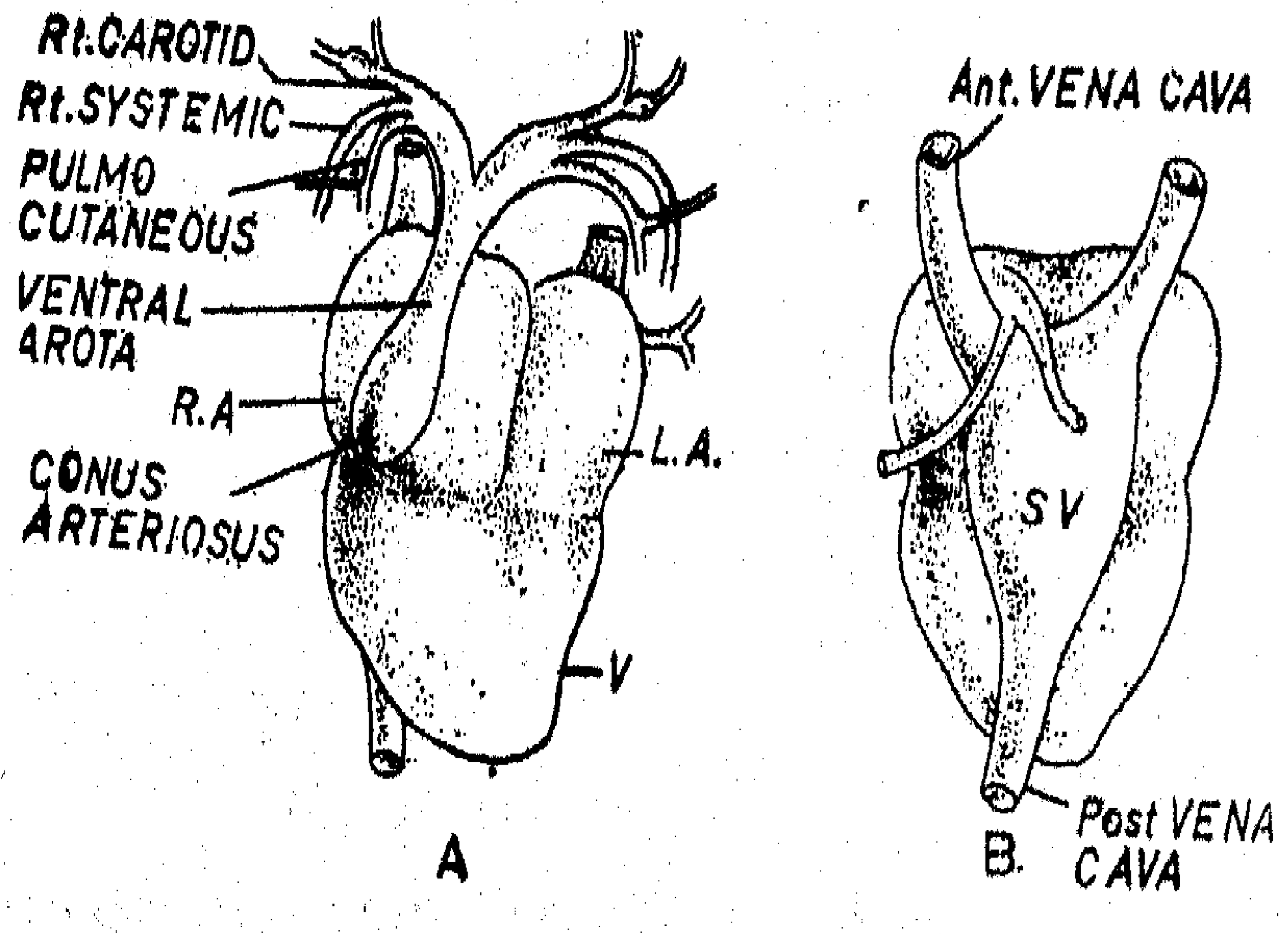


Fig. 117. *Frog Heart—A. Ventral view. B. Dorsal view.*

blood from head, shoulder and fore limbs of the body while the post-caval collects the blood from the remaining posterior region of the body. From the right side of the ventricle, from its ventral aspect, arises a thick-walled muscular tube called *conus arteriosus*, which continues as the ventral aorta (*truncus arteriosus*).

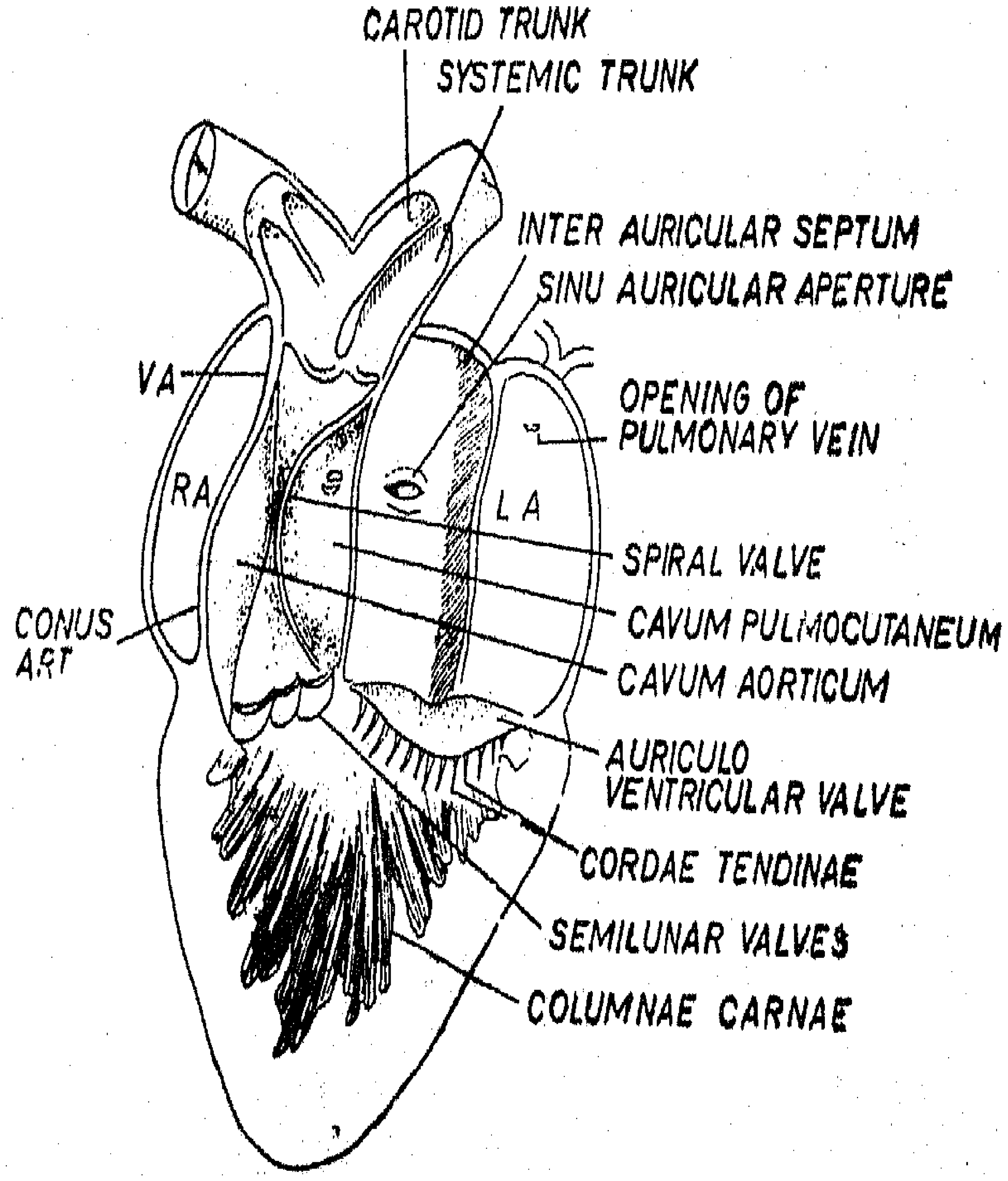


Fig. 118. *Frog Heart—Vertical section*

The two auricles (Fig. 118) are separated from each other by a vertical partition called the interauricular septum. The right auricle is larger than the left. The sinus venosus opens into the right auricle by an aperture called the *sinu-auricular aperture.* This is guarded by a pair of semi-lunar valves which prevent the backflow (*i. e. regurgitation*) of blood from the auricle into the sinus venosus. Both the auricles open into the ventricle by a single aperture, the *auriculo-ventricular aperture.* This aperture is guarded by 4 flap-like valves, called to *auriculo-ventricular valves*. These valves allow the blood to move only from the auricles to the ventricle, and prevent its backflow into the auricles during ventricular contraction. The inner surface of the ventricle is produced into a large number of muscular ridges, the *columnae carneae*, which divide the ventricular space into smaller cavities, the fissures. The opening of the ventricle into the conus is guarded by 3 semi-lunar valves, which prevent the blood from coming back into the ventricle. Inside the conus arteriosus, there is a longitudinal flap, attached dorsally, but free ventrally. Since this takes a spiral turn, it is called the *spiral valve.*

The conus arteriosus is continued further as the truncus arteriosus, which bifurcates into two trunks. Each trunk is comprised of three main arterial branches: (1) the *carotid,* taking the blood to the head: (2) the *systemic* (aortic), uniting with the corresponding arch of the other side to form the dorsal aorta, through which the blood is supplied to the different parts of the body; and (3) the *pulmo-cutaneous*, carrying the blood to the respiratory organs, the lungs and the skin.

It is worth noting that the venous system here includes two portal systems, namely, the hepatic and the renal.

Mechanism of Circulation

The deoxygenated or venous blood collected from the different parts of the body is ultimately brought into the thin-walled sinus venosus by a pair of superior vena cavae and a single inferior vena cava.

The wave of contraction, starting from the sinus venosus, spreads over the entire heart, till the blood is pumped from the conus arteriosus into the ventral aorta. The sinus venosus, because of its contraction, forces the deoxygenated blood through the sinuauricular aperture into the right auricle. At the same time, the oxygenated blood from the lungs is brought into the left auricle by the pulmonary vein. Once the auricles are filled with blood, they contract simultaneously, and drive the blood into the ventricle through the common auriculo-ventricular opening. The backflow of blood from the right auricle into the sinus venosus is prevented by a pair of semilunar valves present at the sinu-auricular aperture.

Similarly, by reason of oblique opening of the pulmonary vein, blood is prevented from re-entering it. In the ventricle, the oxygenated blood that has come from the left auricle and the deoxygenated blood from the right auricle do not get mixed up completely, due to the presence of fissures in the ventricle. This is also partly due to the viscosity of the blood and the negligible time that the blood remains in the ventricle. However, an admixture of the two types of blood does take place in the middle region of the ventricle. Thus, there is dexoygenated blood in the right side, mixed blood in the middle and oxygenated blood in the left side of the ventricle.

Soon after receiving the blood from the auricles, the ventricle contracts, and the blood is forced into the conus arteriosus, which is given off from its right anterior end. Due to the presence of the auriculo-ventricular valves at the auriculo-ventricular opening, the backflow of blood into the auricles is prevented. The contraction wave now spreads on to the conus arteriosus.

The first lot of blood that has entered into the conus is the venous blood, which is forced on to the lungs and skin for oxygenation through the pulmocutaneous trunk. The amount of blood that follows the first lot of venous blood is the mixed blood, which is driven on to the systemic trunks, and to the dorsal aorta and different parts of the body and viscera, in the posterior region. The oxygenated blood present in the left side of the ventricle is the last lot to enter the conus. This blood finds its way into the carotid trunks, which supply this pure blood to the region of the head.

This channelising of the venous, mixed and the oxygenated blood takes place due to the valvular arrangement in the conus arteriosus and the ventral aorta, as well as due to the pressure difference or difference in resistance offered by the three major trunks of the aortic arch.

Since the heart is made up of only 3 chambers, the venous and the arterial blood cannot be kept completely segregated. This double circulation is called imperfect double circulation as the body is not supplied with oxygenated blood. Therefore, the imperfect double circulation is not so efficient as the perfect double circulation found in mammals & birds.

However, it has been established that, when the two auricles contract, the two types of blood, flowing into the ventricle, get throughly mixed, so that the ventricle contains only the mixed blood and not the three types of blood as previously believed. Therefore, all the parts of the body, including the head, receive the supply of mixed blood.

Circulation in fish

Heart of fish (Shark). The heart consists of only two chambers, a single thin-walled auricle and a thick-walled ventricle. (Figs. 119, 120) The auricle (atrium) is situated dorsally to the ventricle. Opening into the auricle by way of a *sinu-auricular aperture* is a thin-walled sac, the *sinus venosus*, which receives the deoxygenated blood from different parts of the body. The auricle opens into the ventricle by the *auriculo-ventricular aperture*. The sinu-auricular as well as auriculo-ventricular apertures are guarded by valves. From the anterior end of the ventricle is given off a *conus arterious*. Inside the conus, there are two rows of valves, which direct the blood flow only in the forward direction. The conus arteriosus extends in front as the ventral aorta, which gives off 5 pairs of *afferent branchial arteries* to the gills situated in the pharyngeal region.

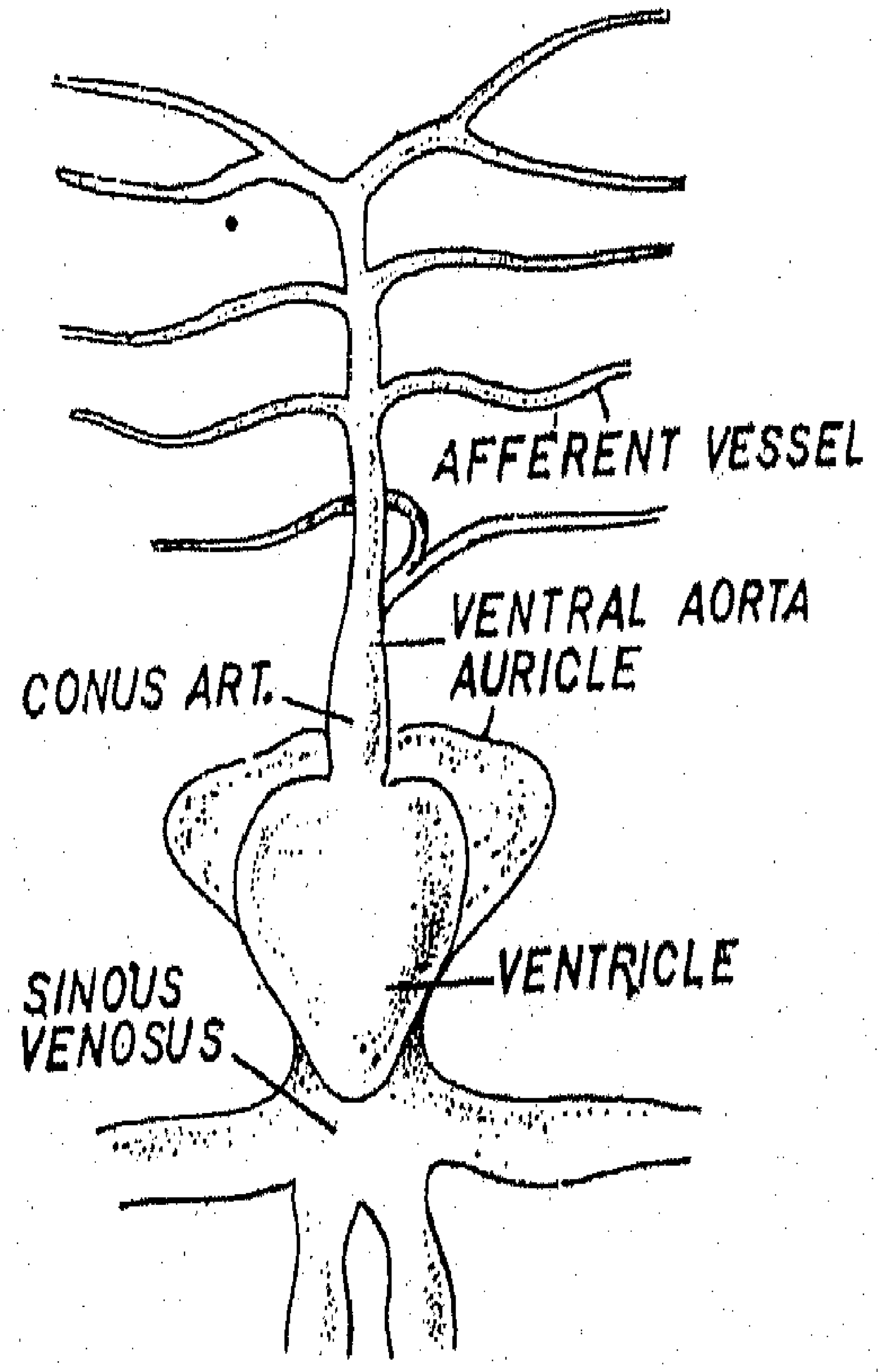


Fig. 119. *Fish Heart—External View.*

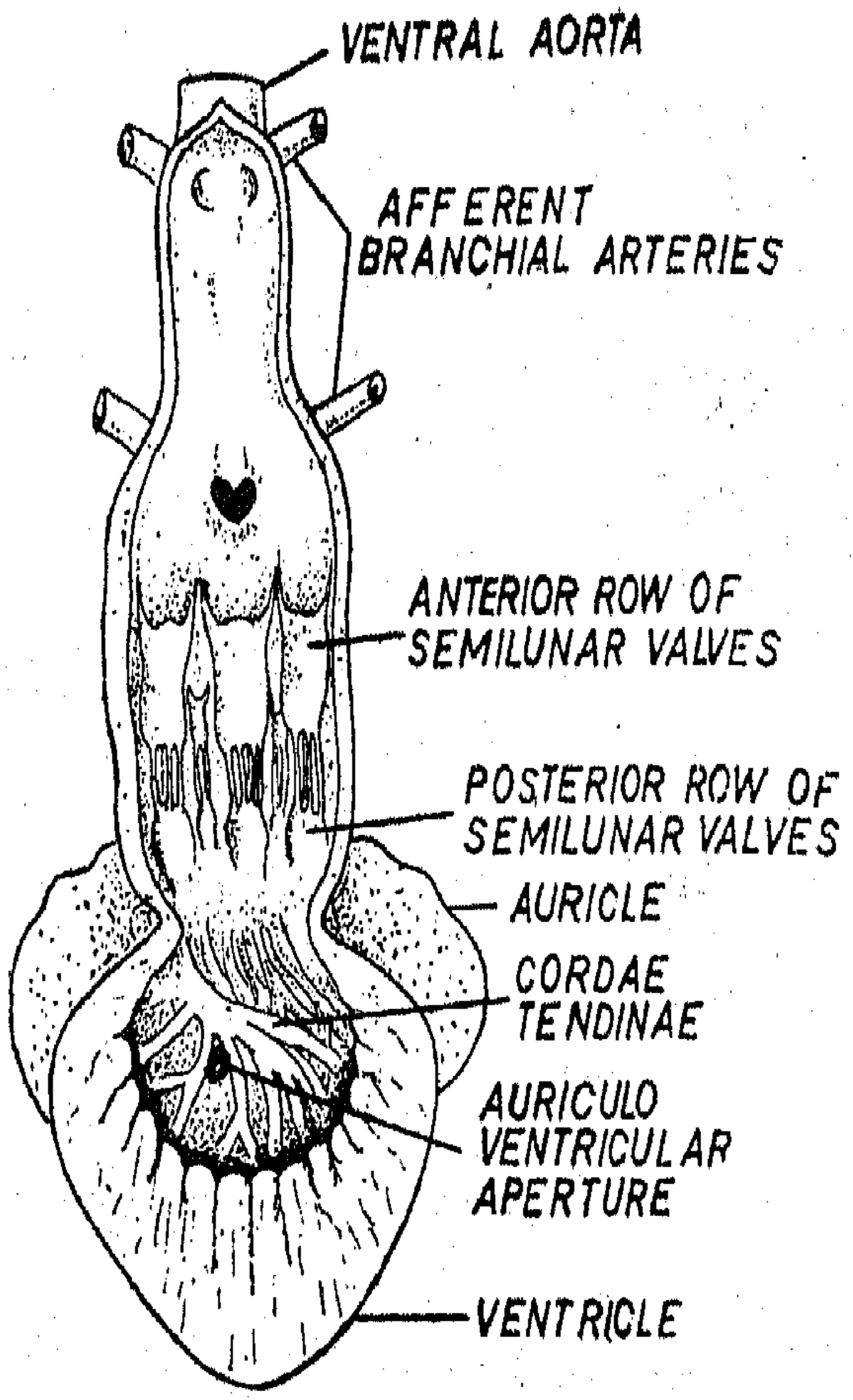

VENTRAL AORTA
AFFERENT BRANCHIAL ARTERIES
ANTERIOR ROW OF SEMILUNAR VALVES
POSTERIOR ROW OF SEMILUNAR VALVES
AURICLE
CORDAE TENDINAE
AURICULO VENTRICULAR APERTURE
VENTRICLE

Fig. 120. *Fish Heart—Vertical Section*

Course of circulation. The venous blood is brought to the sinuvenosus from different parts of the body. The contraction wave spreading from the sinus venosus to the auricle and then to the ventricle, drives the blood to the conus arteriosus, from where it is driven into the ventral aorta. (Fig. 121) The ventral aorta distributes the blood to the gills for oxygenation by way of the *afferent branchials*. The blood that is oxygenated in the gills is collected by another set of blood vessels called the *efferent branchials*, which unite to form the dorsal aorta. This distributes the aerated blood to different parts of the body, where it gives off its O_2 to the tissues. The deoxygenated blood is brought to the sinus venosus by the venous system.

Oxygenated blood in fishes does not come back to the heart at any time. Only the deoxygenated blood is brought to the heart for pumping it on to the gills for oxygenation. Thus there is only a *single circulation.*

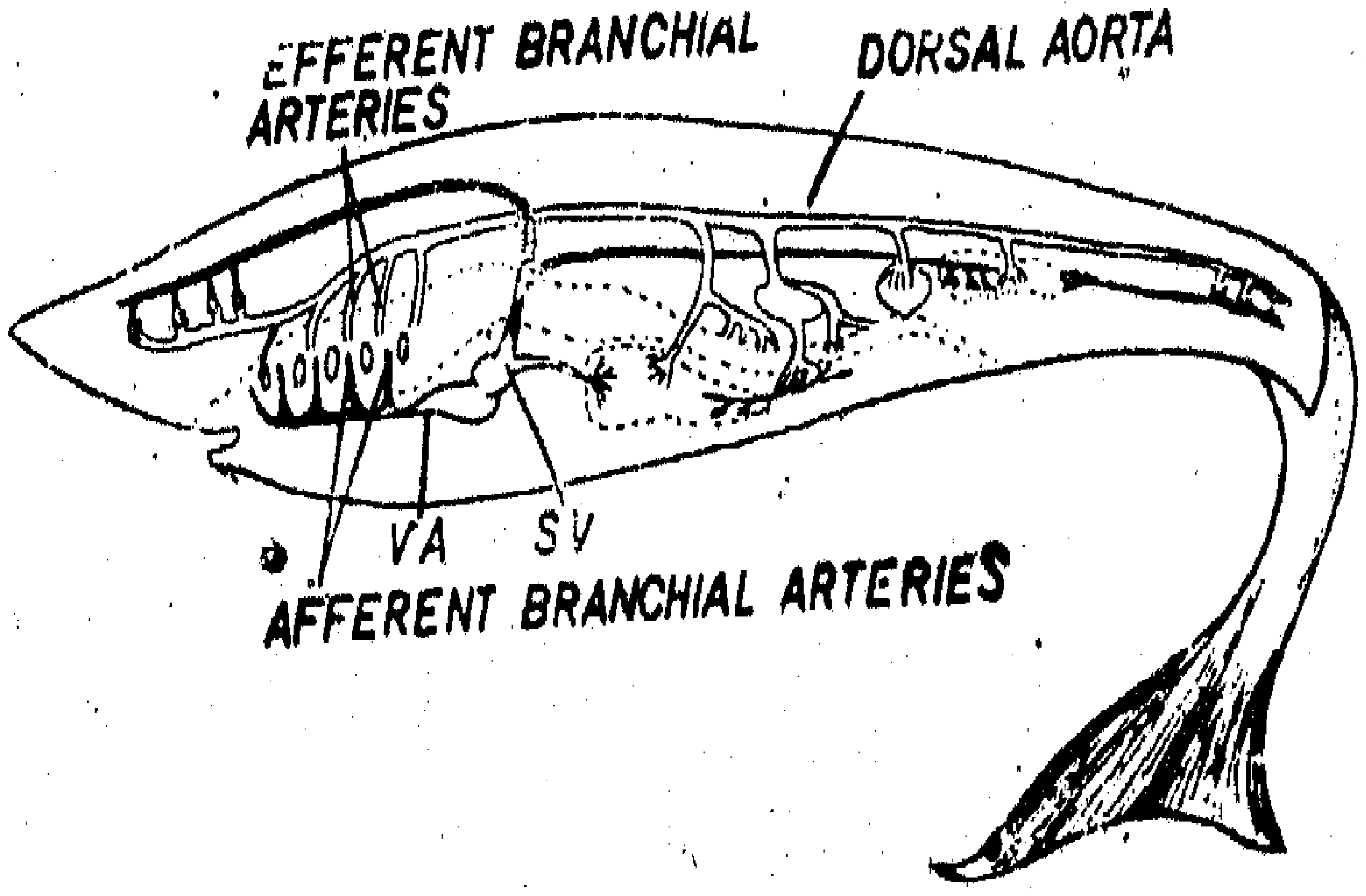


Fig. 121. *Shark—Circulating System*

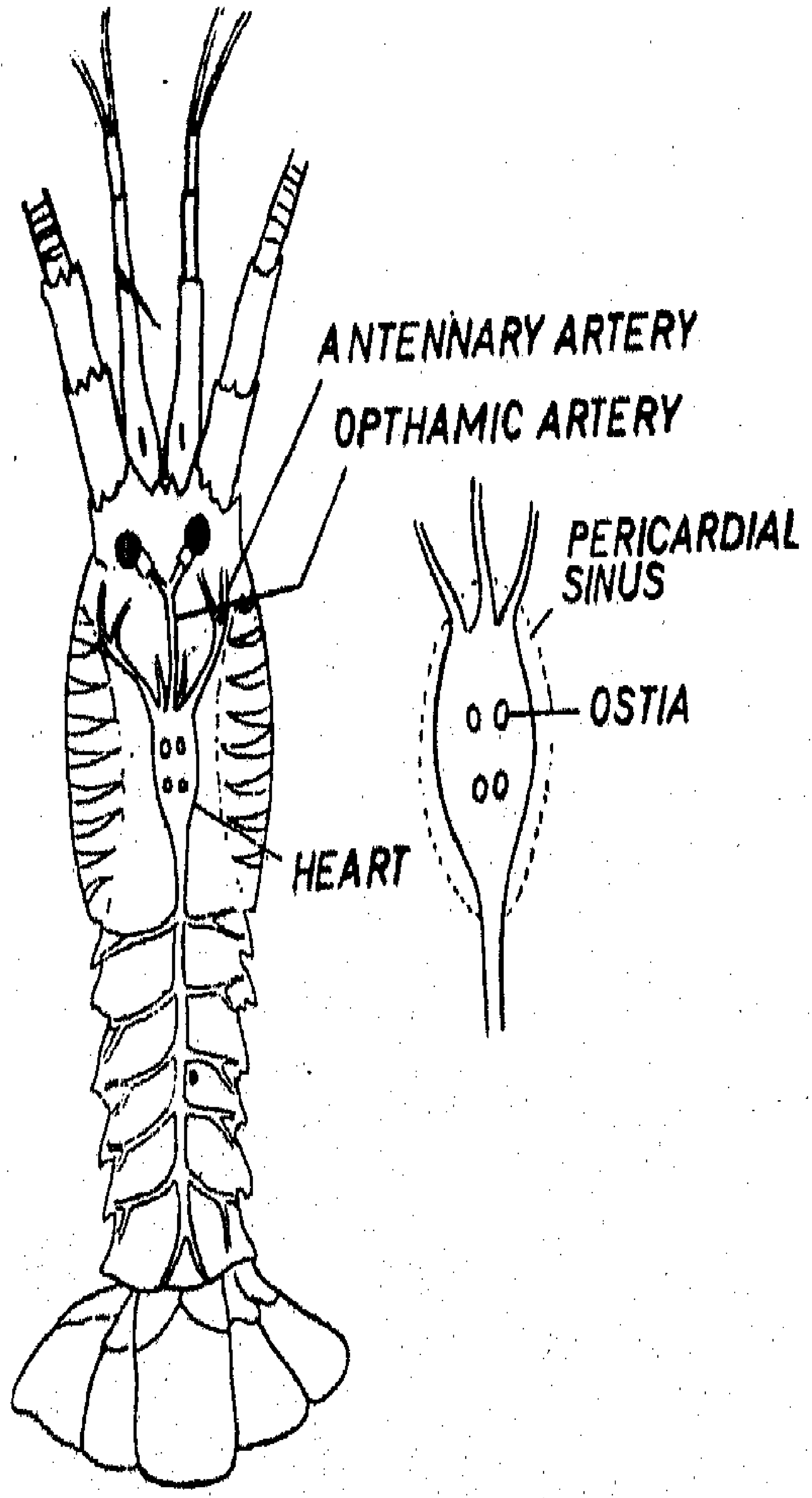
Since the heart always contains venous blood, it is referred to as the *venous heart.*

Circulation in lobster

In lobster, the blood is slightly bluish. This is due to the presence of a respiratory pigment called *haemocyanin,* a compound containing copper. It is dissolved in the plasma, instead of being present in the blood cells, as in the vertebrates. Like haemoglobin, it has affinity towards oxygen and is an oxygen-carrier. A large number of amoeboid corpuscles (white blood cells) are found in the plasma.

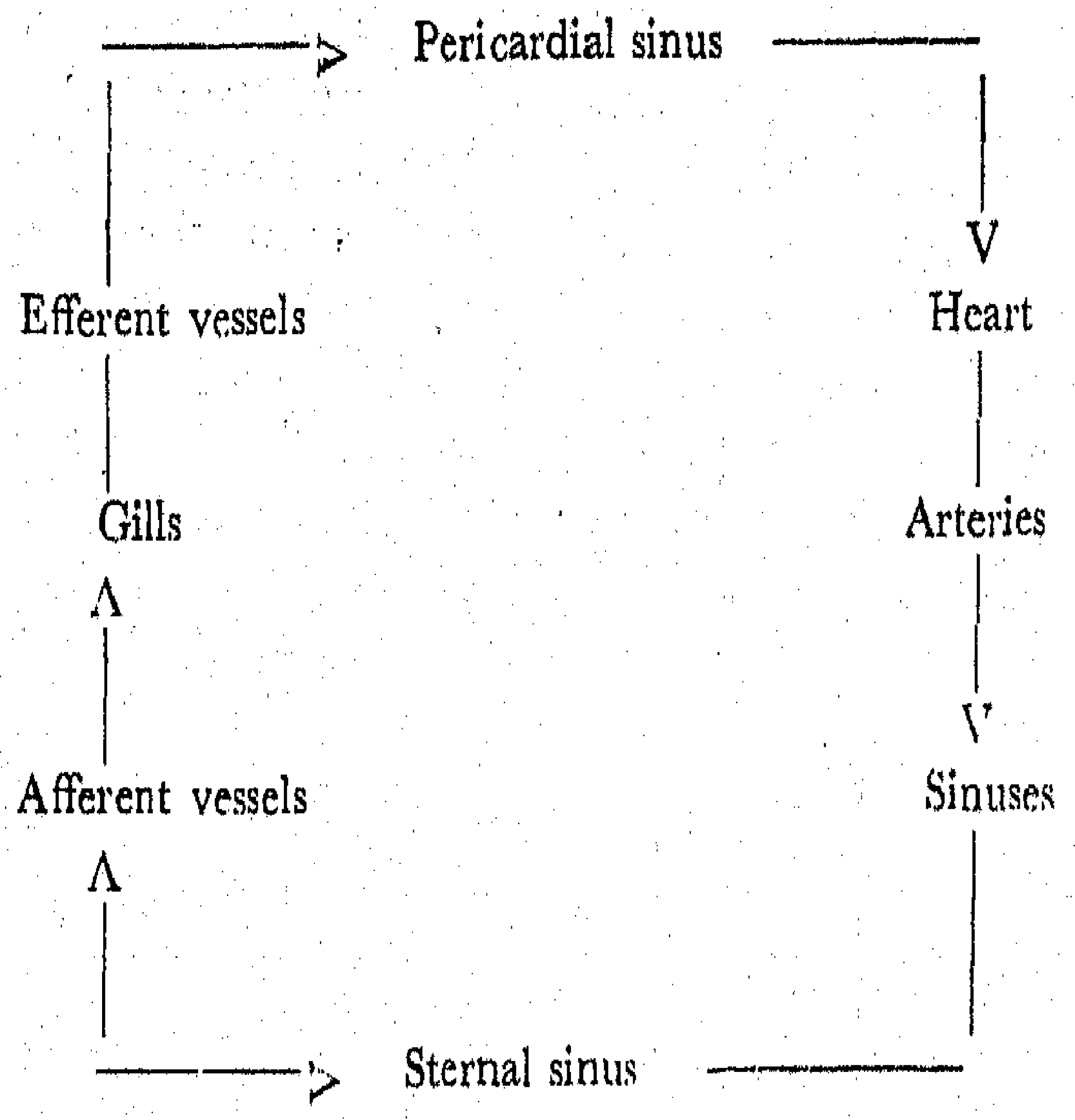
Heart of lobster. The heart is a single-chambered muscular organ found on the dorsal side in the *cephalothoracic* region. (Fig. 122) It is suspended in a fluid-filled space or *sinus* called the *pericardial sinus.* The heart is provided with six openings called as ostia. These are provided with valves. They allow the blood to flow from the surounding pericardial sinus into the heart when it dilates, and do not allow the reverse flow of blood back into the pericardial sinus when it contracts.

The circulatory system consists of the heart, arteries and open spaces, called *sinuses,* which collect the blood. There are no veins. Instead, there are present the open spaces, called sinuses. When the heart contracts, the blood contained in the heart is driven into the arteries that are given out from the heart in front and from behind. The arteries distribute the blood to all parts of the body. The deoxygenated blood is taken away from the different organs by various sinuses which ultimately open into one large sinus on the ventral side, called the *sternal sinus.*



Eig. 122. *Lobster Circulatory System*

From the sternal sinus, deoxygenated blood is sent to the respiratory organs, the gills, situated on either side of the cephalothoracic region. Here, the blood gets oxygenated. This blood comes into the pericardial sinus. From the pericardial sinus, it enters the heart through the ostia when the heart dilates.



Blood—Earthworm

In an earthworm, the blood is red in colour. The respiratory pigment is haemoglobin, similar to the one found in vertebrates; but this haemoglobin is dissolved in the plasma and not found in the blood cells. The plasma contains a large number of amoeboid cells (white blood cells).

SUMMARY

1. Circulatory system is responsible for the circulation of blood and lymph.
2. In higher animals there is a closed circulatory system while in insects there is an open circulatory system.
3. Blood consists of plasma and corpuscles or cells the latter being of three types namely (1) R. B. C. (2) W. B. C. and (3) Thrombocytes.
4. R. B. Cs are circular, biconcave and red in colour due to the pigment haemoglobin.
5. W. B. Cs are colourless nucleated and have no definite shape.

6. Thrombocytes are very small, and non-nucleated.
7. The blood carries out a number of functions as like carrying food, oxygen, CO_2, waste products, maintenance of body temperature, defence against bacteria, and blood clotting.
8. Spleen is a lymph node which destroys worn out red blood corpuscles and produces white blood corpuscles.
9. The human heart is four chambered while that of frog and fish is three chambered and two chambered respectively.
10. The heart of fish never receives oxygenated blood.
11. The heart of lobster is one chambered which contains oxygenated blood only.
12. The blood of earthworm is red in colour. Here the pigment is not found in blood cells but dissolved in the plasma.
13. The blood of lobster on other hand is bluish due to the presence of a pigment called haemocyanin.

BIOLOGICAL WORDS

Plasma
Thrombocytes
Lymph
Auricle
Ventricle
Capillary
Sinus venosis
Pericardial Sinus

QUESTIONS

1. What is blood? Describe the composition and functions of the blood. How does it clot?
2. Describe the structure of human heart.
3. Describe the internal structure of the heart of frog and add a note on the mechanism of circulation.
4. Write short notes on:—
   (1) Heart of fish, (2) Lymph, (3) Blood of earthworm, (4) Heart of lobster.
5. Distinguish between:—
   (a) Artery and Vein, (b) Double and single circulation, (c) Open and close circulation, (d) Red blood cell and White blood cell,

(e) Blood and Lymph, (f) Haemoglobin and Haemocynin, (g) Blood of earthworn and blood of frog.

6. Describe the human heart and state in which points it differs from the heart of frog.

7. Give one important function of the following :—

(i) Red blood cell, (ii) White blood cell, (iii) Heart of fish, (iv) Fibrinogen.

8. Fill in the blanks :—

(a) Blood contains——, in which is present——and this helps in respiration.

(b) White blood cell act like——.

(c) Clotting of blood is brought about with the help of——,——, ——, and——,

9. State whether the following statements are true or false, if false give reasons.

1. Red blood cells protect the body.
2. Thrombocytes help in respiration.
3. Arteries have valves.
4. Veins are thin walled.
5. In lobster there is closed type of circulatory system.
6. In Fish there is single circulation.
7. Auricles are thick walled and venticles thin walled.
8. Heart of fish is called as venous heart.
9. Blood of Earthworm is red in colour because it contains red blood cells.

Respiration

10

The metabolic activities of every cell require a special form of kinetic energy, called chemical energy. This energy is obtained from the food which contains potential energy. This conversion is done by the *dehydrogenation* of food in the cells.

Respiration is a biochemical process of dehydrogenation of organic nutrients in the cells, releasing chemical energy and carbon dioxide.

The process involves two phases.

(1) **External respiration,** in which the exchange of gases takes place between the surrounding medium (either water or air) and the fluid (blood) in the respiratory organs.

In mammals, birds and reptiles, the external respiration takes place in the lungs (*i.e.*, Pulmonary or lung respiration). In fishes, it takes place in the gills (*i.e.*, Gill respiration). In frogs, it takes place in the lungs, buccal cavity and skin.

(2) **Internal respiration** (or Cellular or Tissue respiration, in which the exchange of gases takes place in the tissues and cells; and the oxygen is utilised for the oxidation of the nutrients to release the necessary energy.

Respiratory system of man

The respiratory system in man consists of a pair of lungs, —which are the essential organs of respiration and where the exchange of gases takes place—and also certain accessory organs, such as the air passages. Air passages include the *nasal passage*, *pharynx*, *trachea*, *bronchi* and the *bronchioles*. Apart from the lungs and the air passages, there are also the ribs and the diaphragm, which help in respiration.

The right lung is divided into three lobes while the left one is divided into two lobes.

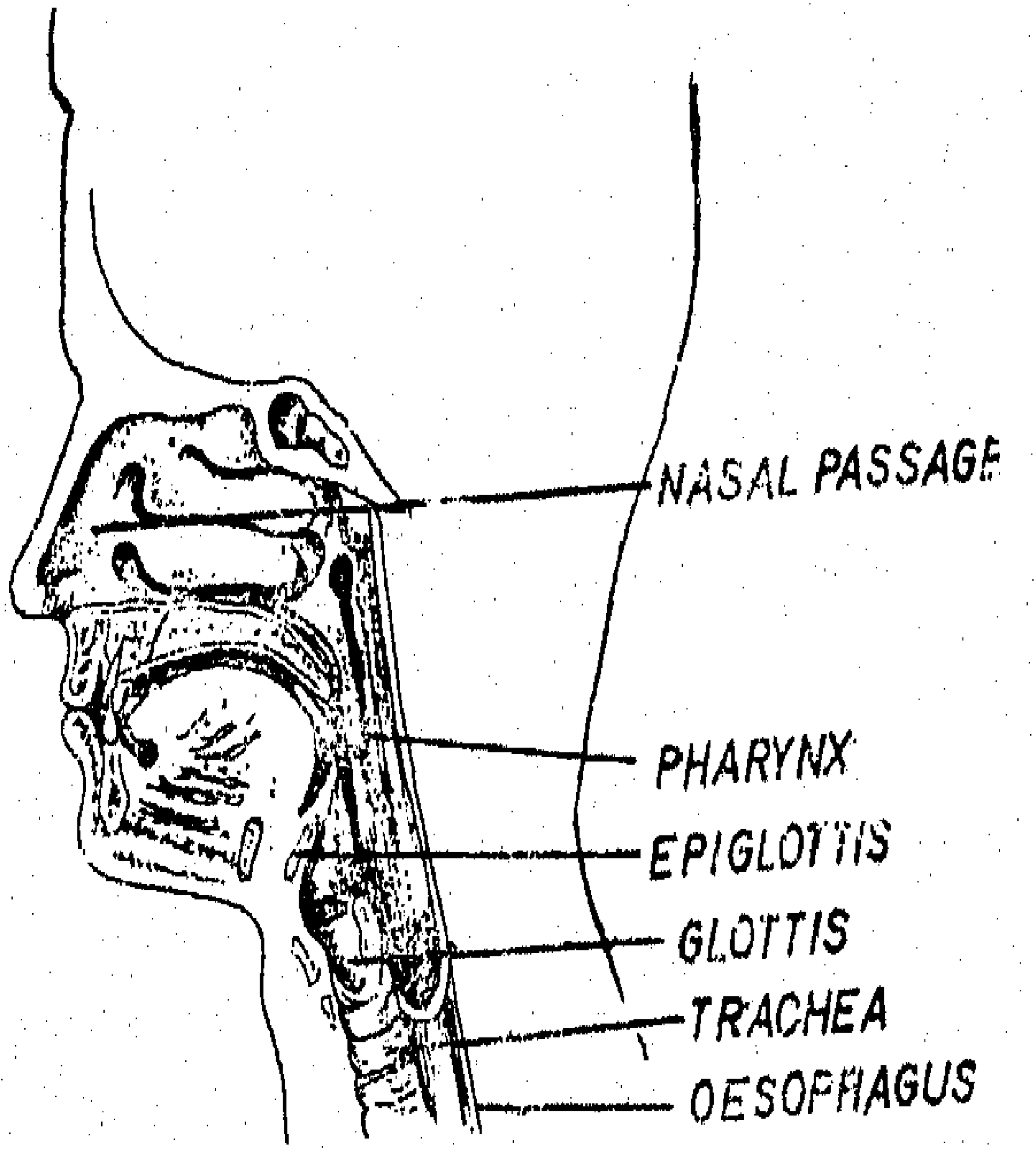


Fig. 123. *Human—Air Passage.*

The air passage begins with a pair of external nostrils, each leading into the nasal cavity. (Fig. 123) The nasal cavity is lined with mucosa and hairs. The air is filtered and warmed as it passes through the nasal passage. This cavity opens into the pharynx by an internal nostril. The pharynx is the common passage for the digestive system as well as the respiratory system. Situated in the pharynx is an opening called *glottis*, which leads into the wind-pipe or *trachea*. The glottis is guarded by a cartilaginous flap called the *epiglottis*, which prevents the food from getting into the wind-pipe during swallowing, by closing the glottis. The anterior end of the trachea is modified into a sound-producing organ, the sound box or *larynx* which is supported by special cartilages and muscles. Internally, there is a pair of well stretched membranes, the *vocal cords*, with a slit-like opening between them. The vibrations of these vocal cords, by the outgoing air during expiration, help in the production of sound.

The trachea is a soft tube (Fig. 124), which is strengthened by C-shaped cartilaginous tracheal rings which prevent its collapse. The trachea runs downwards into the thoracic cavity, where, it divides into two main branches, which are known as *bronchi* (singular, *bronchus*), each entering the lung of its side.

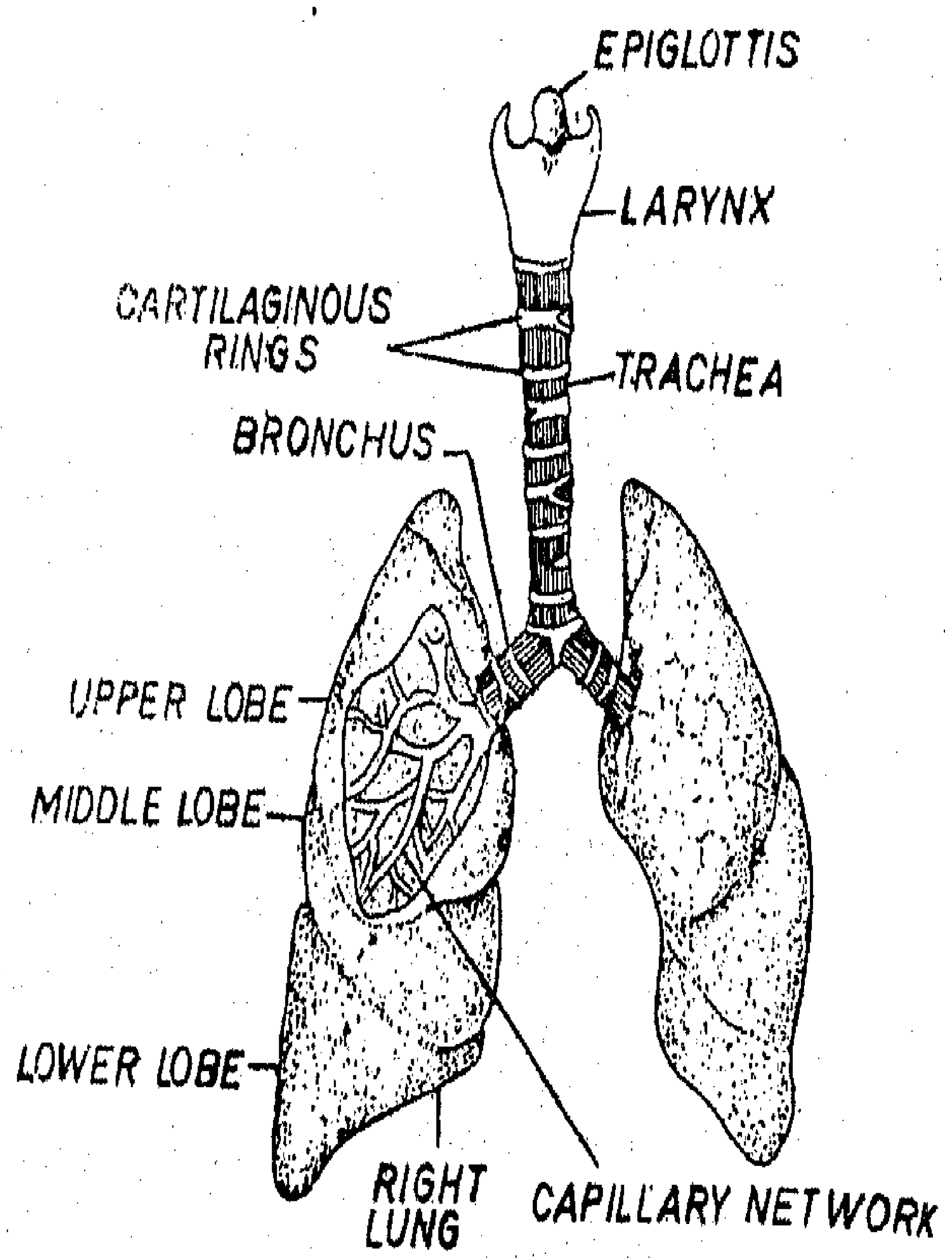


Fig. 124. *Human—Respiratory System*

The lungs are soft, spongy, elastic, bag-like structures found one on either side in the chest or thoracic cavity. They are pinkish-grey in colour, and are bounded by a double membrane called the *pleural membrane.* There is a thin fluid present between the two membranes, which prevents any friction between the membranes and helps in the free movements of the lungs. The right lung is divided into three lobes, while the left one is divided into two lobes. Within the lung, each bronchus repeatedly divides, forming smaller and smaller secondary bronchi. These, in turn, branchi into still smaller tubes, called the bronchioles. Each ultimate terminal bronchiole then ends up into enlarged thin-walled groups of microscopic air chambers or pouches called alveoli (singular, alveolus) (Fig. 125). The alveoli are thin-walled bags, made up of a single layer of flat cells, and are semi-permeable. They are vascular, for they are invested by blood capillaries of the pulmonary artery and the pulmonary vein. Due to their thin walls and capillary ramifications, the alveoli are the regions

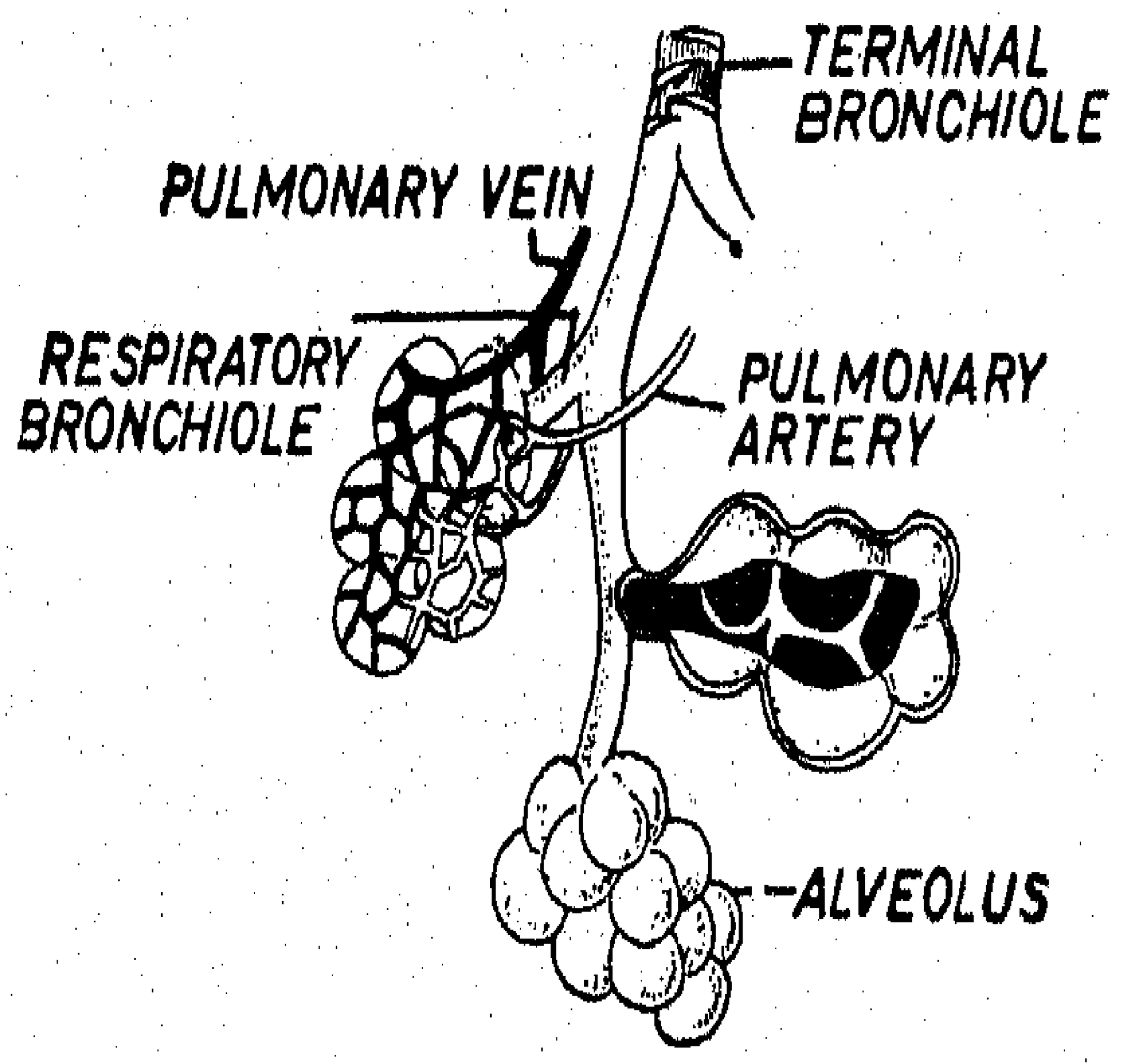


Fig. 125. *Alveoli*

where the exchange of gases takes place. They also serve to increase many fold the surface area for the exchange of gases. The alveolus is a unit of pulmonary respiration.

Mechanism of Pulmonary Respiration

The thoracic cavity, containing lungs, is separated from the lower abdominal cavity by a muscular sheet or partition, called the diaphragm. (Fig. 126) In its relaxed state, it is *dome-shaped* or arched upwards. The chest cavity is bounded laterally, in front and behind by the ribs. These curved bar-like bones are attached in front to the breast-bone or sternum and behind to the vertebral column. In between the ribs are present the *inter-costal muscles*. It is the diminution and expansion of the thoracic cavity by which the air is breathed out or breathed in. The breathing in of air is called *inspiration* or inhalation, and the breathing out is called *expiration* or exhalation.

Inspiration. During inspiration, the inner intercostal muscles contract, bringing about the lifting up of the ribs. At the same time, the diaphragm, is lowered by the contraction of its muscles. This brings about an increase in the volume of the thoracic cavity, and creates a reduction in pressure over the lungs. Lungs, being elastic and connected to the outside, through the bronchi, trachea and the nasal passage, expand, drawing in fresh air from the atmosphere. Air fills in the alveoli. This intake of air into the lungs is called inspiration.

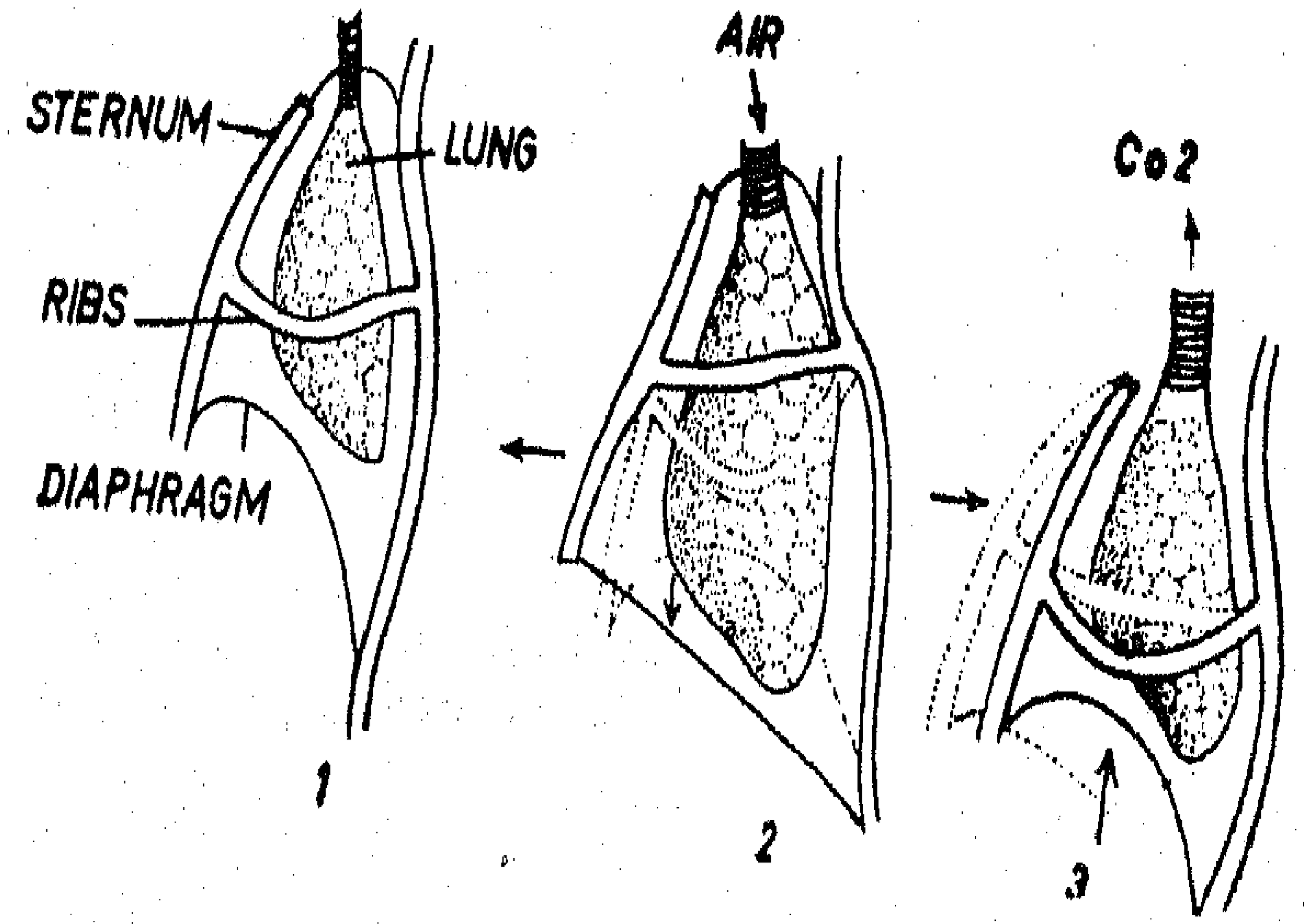


Fig. 126. *Mechanism of respiration (Diagrammatic)*
1. At rest 2. Inspiration 3. Expiration

The exchange of gases takes place through the semi-permeable, vascular walls of the alveoli and the capillary lining. O_2 from the alveoli of the lungs diffuses into the blood, and the CO_2 from the blood within the capillaries diffuses into the alveoli. This exchange of gases takes place due to the high percentage of O_2 in the alveolar air and lesser percentage of O_2 in the blood of the capillaries. Similarly, the CO_2 percentage is higher in the blood and there is lesser concentration of CO_2 in the alveoli. This exchange is further assisted because of the affinity of respiratory pigment, haemoglobin, for O_2. Haemoglobin is able to absorb large quantities of O_2 forming an unstable compound called oxyhaemoglobin, which imparts to the blood a scarlet colour. Venous blood is purplish red because the haemoglobin is in a deoxygenated state.

Expiration. During expiration, the outer inter-costal muscles contract and bring about the lowering of the ribs. The diaphragm comes to its arched position due to the relaxation of its muscles. Thus, the volume of the thoracic cavity is reduced, which brings about a pressure on the lungs. This is further aided by the elastic recoil of the lungs. The air, which is deprived of its O_2 and is now full of CO_2 and water vapour, is thrown out of the lungs. This process of expulsion of foul air from the lungs is called *expiration*.

Respiratory System in Birds (Pigeon)

It is modified in accordance with their flying habits. The air passage begins with a pair of external nares, situated at the base of the beak. The nasal passage opens into the pharynx through the internal nare. The pharynx leads into the trachea through an opening, the glottis. The epiglottis is absent. The glottis is followed by the larynx which does not produce sound in birds. The trachea enters the thorax and bifurcates into right and left bronchi, each of which enters the lung of its own side. (Fig. 127). At the junction of the two bronchi with the trachea, there is a specialised sound producing organ of the birds, the *syrinx*, which is found in no other animals.

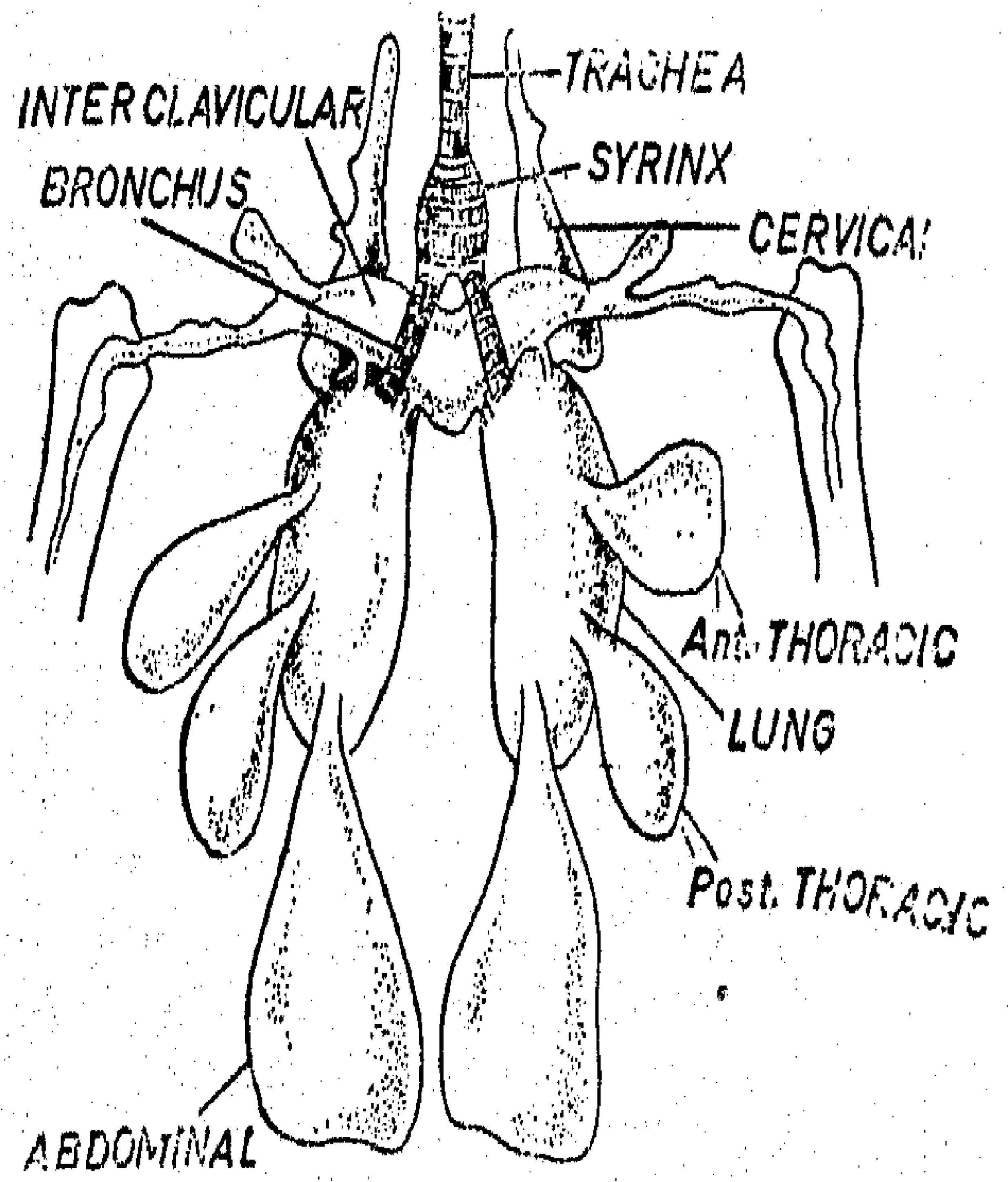


Fig. 127. *Pigeon—Respiratory System.*

The lungs are very small in comparison with the size of the bird, and are but slightly distensible as they are attached dorsally to the ribs, and are not freely suspended, as in mammals. They are much more elaborate, being spongy internally. They are highly modified to suit the needs of the birds in securing the maximum amount of O_2 for the production of a greater amount of energy required by them. Its efficiency is further increased by the presence of certain special accessory organs called *air sacs*. These air sacs are thin-walled, membranous, non-vascular bags, which open into the lungs and are connected directly with the branchioles. Each lung has a cervical, an anterior thoracic, a posterior thoracic, and an abdominal air sac attached to it. In addition there is a single-median inter-clavicular air sac, which lies anteriorly and communicates with both the lungs. Thus, in all, there are 9 air sacs. These air sacs send minute branches into the different bones of the body, making them lighter. Being non-vascular, no exchange of gases takes place in them. They merely serve as reservoirs of air. They increase the buoyancy of the body by storing warm air. They help in maintaining the balance of the body. They regulate and maintain a high body temperature. They act as bellows and force the air in and out of lungs. They expel all the foul air from the lungs completely during expiration. Besides the branches to the air sacs, the main bronchus of the trachea gives off secondary bronchii, and these branch again, sending off tubes which give rise to a system of fine branching and anastamosing tubules, the *lung capillaries*, which along with the blood capillaries, make up the substance of the lung. There are no alveoli.

Mechanism of Respiration

There is no diaphragm and the ribs are not freely movable. The mechanism of respiration, therefore, is brought about with the help of the sternum and the vertebral column. When the bird is not flying, the alternative elevation and depression of the sternum, produced by the abdominal and the inter-costal muscles, causes an alternate enlargement of, and diminution in, the capacity of the body cavity, and pumps the air in and out of the lungs. However, during flight, when the weight of the body is supported by the wings and the sternum is rendered immovable, the same effect is produced by the elevation and depression of the back, *i.e.*, the vertebral column. The inspired air rushes into the lungs and also into the air sacs through the lungs. The exchange of gases takes place in the lungs and not in the air sacs. During expiration, the foul air from the lungs is expelled. This is followed by the squeezing out of the fresh air from the air sacs into the lungs, where it is deprived of its O_2 content before it is finally expelled. Thus, in birds, the exchange of gases takes place twice, once during inspiration and again during expiration. As a result of this, the aeration of the blood is very complete, and its body temperatue is correspondingly high.

Inspiration in birds is a passive process, while expiration is an active process. In mammals, however, it is just the opposite.

Respiratory System in Frog

The frog is amphibious and is capable of using the free O_2 of the air and the dissolved O_2 from water. It can respire through the skin (*cutaneous respiration*), buccal cavity (*buccal respiration*), as well as through the lungs (*pulmonary respiration*).

Pulmonary respiration. The air passage begins with a pair of external nostrils (*nares*), situated at the tip of the snout.

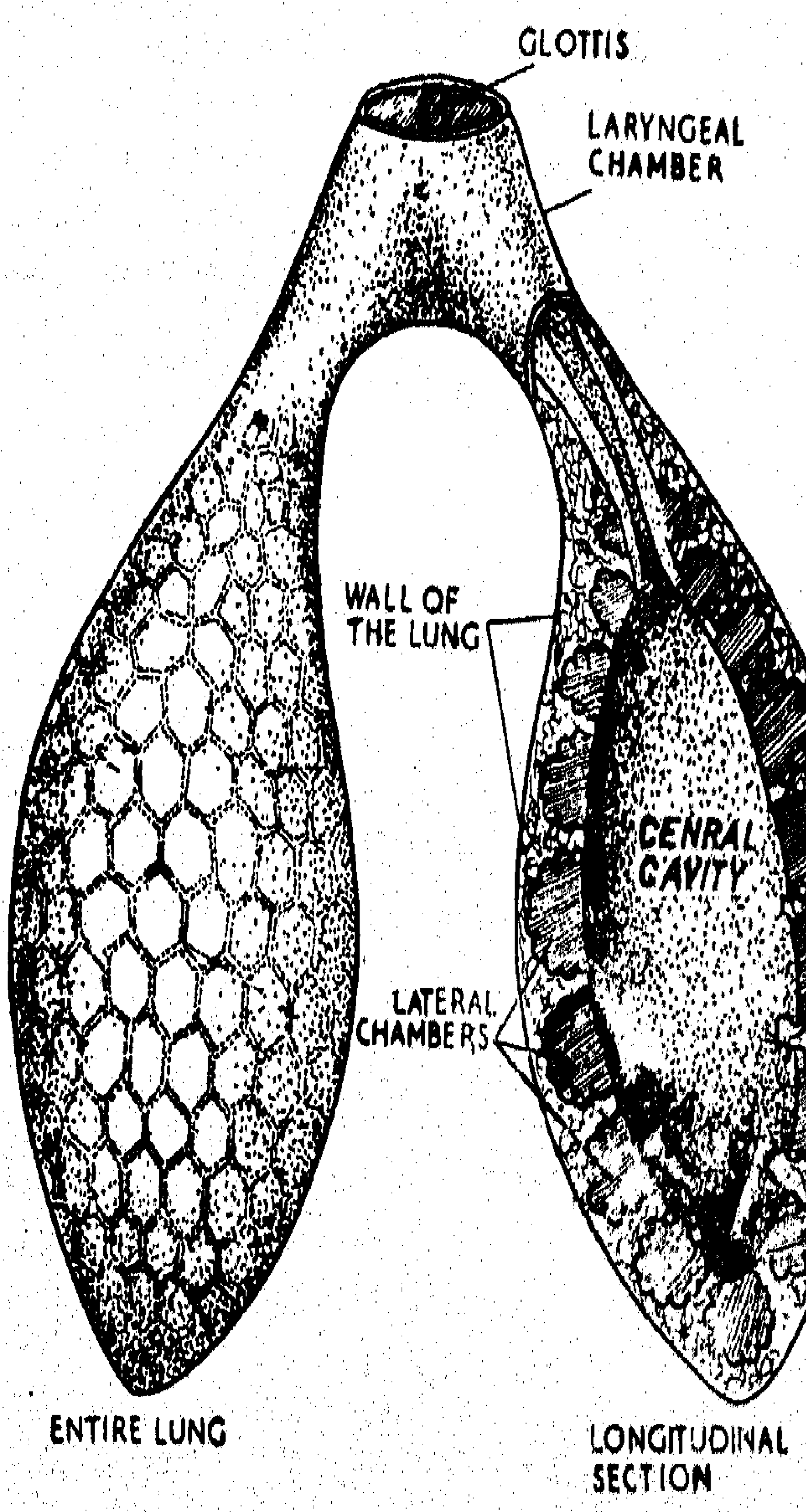


Fig. 128. *Frog—Respiratory System.*

The nasal passage opens internally by the internal nare into the buccal cavity, which is followed by the pharynx. The respiratory opening in the pharynx is a slit-like aperture, the glottis. (The epiglottis is absent.) The glottis leads into a chamber called the *laryngo-tracheal chamber.* This chamber is supported by cartilages and is provided with vocal cords, which form the sound-producing organ. There is no trachea. The laryngo-tracheal chamber is directly connected with the two lungs.

These lungs (Fig. 128) are elastic, fusiform bag-like structures, suspended in the anterior part of the body cavity. Each lung encloses a spacious central cavity. Internally, it is divided into a large number of lateral chambers by the transverse connective tissue septa containing blood capillaries. The inner epithelial lining of the lung is thrown in the form of small spaces or chambers called alveoli, which are richly supplied with blood capillaries. This increases the respiratory surface area for gaseous exchange. The presence of smooth muscle fibres and elastic connective tissue in the lungs gives them an elastic nature.

Mechanism of Pulmonary respiration. Pulmonary respiration takes place in three phases (Fig. 129).

(1) *Aspiration*, during which fresh air is taken into the buccal cavity.

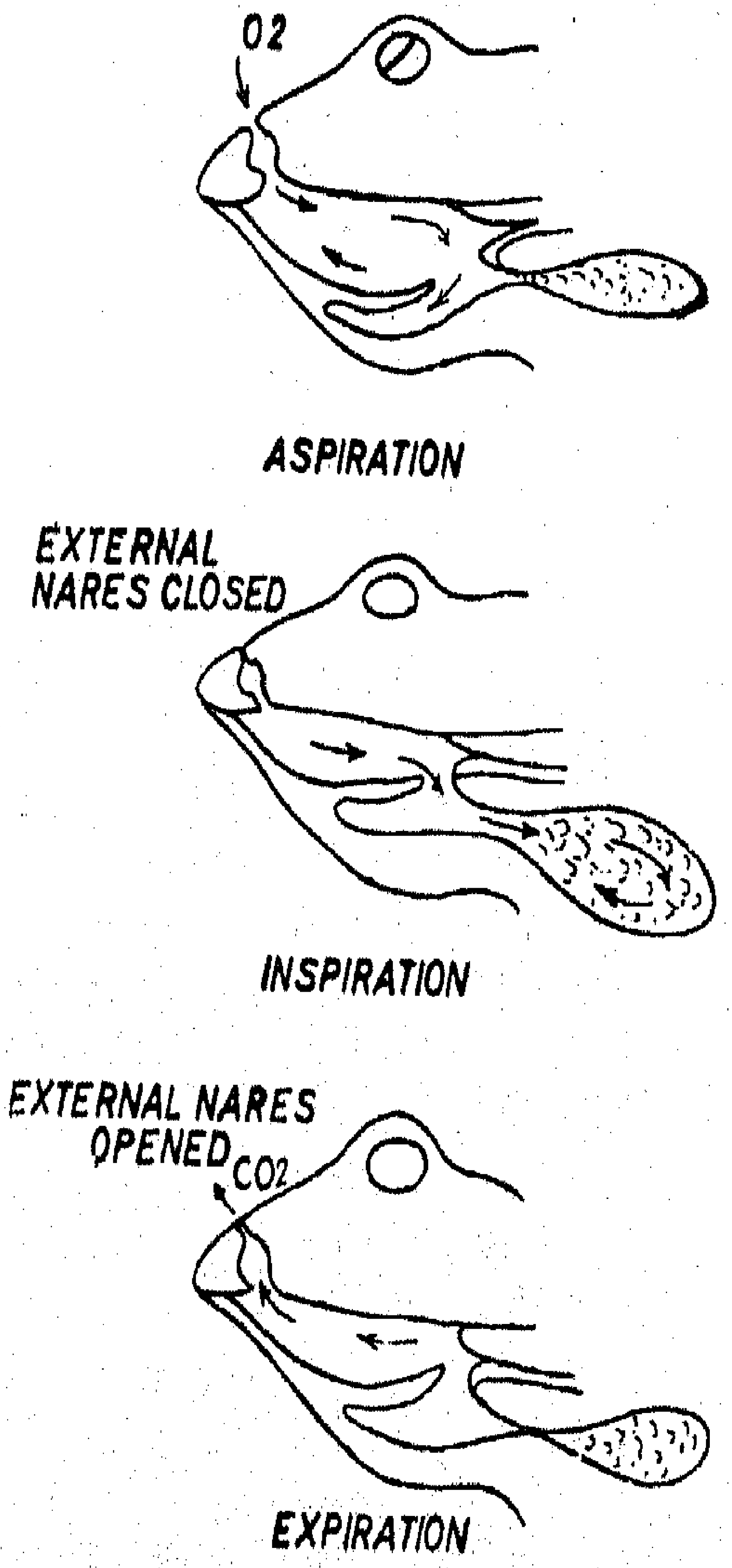


Fig. 129. *Frog—Mechanism of Respiration (Diagrammatic)*

(2) *Inspiration* is the process in which the fresh air from the buccal cavity is forced into the lungs.

(3) *Expiration* is the process in which the foul air is driven from the lungs to the outside through the buccal cavity.

Aspiration. During aspiration, the mouth is kept closed, while the nostrils are kept open. The floor of the buccal cavity is lowered by its muscles. This increases the volume of the buccal cavity. As the pressure within this cavity is reduced, air from the outside is drawn into it through the nostrils and the nasal passage.

Inspiration. During inspiration, the nostrils are closed by the lifting of the movable premaxillary bone, present at the tip of the upper jaw, following an upward thrust from the lower jaw. The floor of the buccal cavity, is raised increasing the pressure in the buccal cavity as a result of the reduction in its volume. The air is thus forced into the lungs, through the glottis.

This air fills up the alveoli of the lungs. The exchange of gases takes place in the lungs. O_2 from the air diffuses into the blood and the CO_2 from the blood diffuses out into the alveolar air.

Expiration. Expiration of air takes place because of the contraction of the body wall, which brings about pressure to bear upon the lungs. This is further assisted by the elastic recoil of the lungs themselves. During this process of expiration, the floor of the buccal cavity is lowered, and the air, which is under pressure in the lungs, passes into the buccal cavity. It is then expelled by the simultaneous opening of the nostrils and the raising up of the floor of the buccal cavity.

Buccal respiration. The inner surface of the buccal cavity is lined with mucosa, which is an epithelium richly supplied with blood capillaries. When the air is retained in the buccal cavity for some time, an exchange of gases takes place. During this process, both the mouth and the glottis are closed, nostrils are kept open, and the floor of the buccal cavity is alternately lowered and raised, and air is pumped in and out of the buccal cavity.

Cutaneous respiration. The skin is smooth and naked without any scales. It is kept moist by the mucus secreted by the mucous glands. It is vascular, being richly supplied with a network of blood capilllaries of the cutaneous artery and the vein. The skin serves as an important respiratory organ. The exchange of gases takes place over the surface of the skin, between O_2 of the surrounding medium (air or water) and CO_2 of the blood in the capillaries. It is the only type of respiration that takes place when the animal is in water or undergoing winter sleep, *i.e.*, hibernation. It is believed that, through the skin, a large amount of O_2 is taken in than through the lungs, when it is outside the water.

Respiratory System in Fishes

Fishes, being aquatic, breathe O_2 dissolved in water. Hence the specialized respiratory organs are the gills, which are borne on either side of the pharynx. (Fig. 130 A) Each gill is supported by a hard and hollow *gill arch* or branchial arch (Fig. 131A), which gives rise to *gill rays*. On the inner border of each gill arch are certain processes which are called *gill rackers*, and which help in collecting the food as well as preventing any substance, present in water, from getting collected over the gills. The mucosa or the epithelial lining of the gills is produced in a double row of

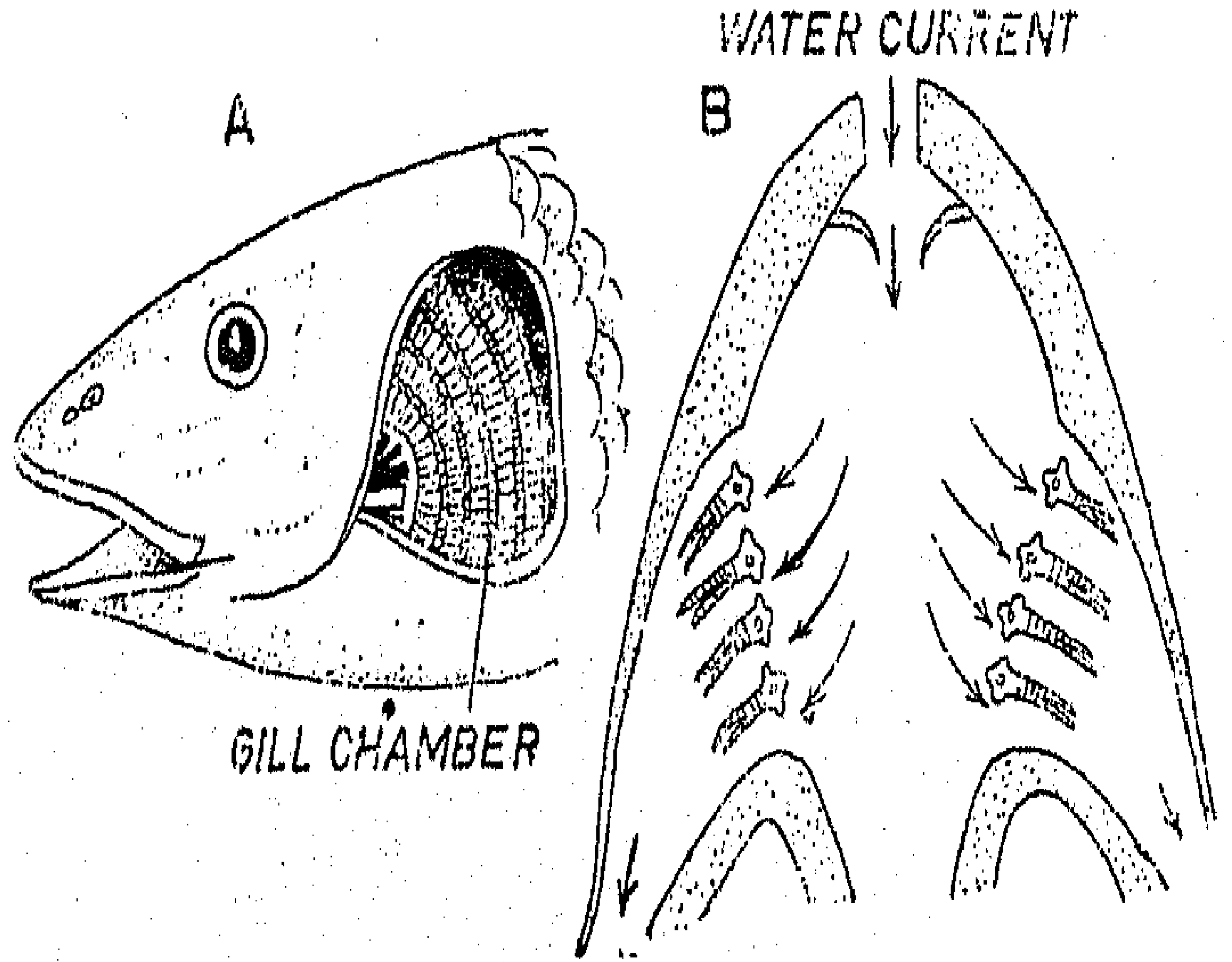


Fig. 130 A. *Fish—Gill chamber* **B.** *Course of respiratary current*

a large number of thin-walled tubular *gill filaments* (Fig. 131 B). These are supported by the gill rays. Entering each gill arch is an *efferent branchial* blood vessel of the ventral aorta, which brings in deoxygenated blood to the gills. This divides into fine capillaries within these filaments. The gill arch also contains an *efferent branchial* blood vessel, which is formed by the union of these capillaries. The gills are separated from one another by *gill slits* or gill clefts. They communicate internally with the pharynx and externally to the outside. In cartilaginous fishes, the gill clefts open to the outside independently, while in bony fishes the gills are covered on the outside by a bony lid called the *operculum*. Thus, all the gills in bony fishes lie inside the branchial chamber, and the entire chamber opens to the outside by a single aperture.

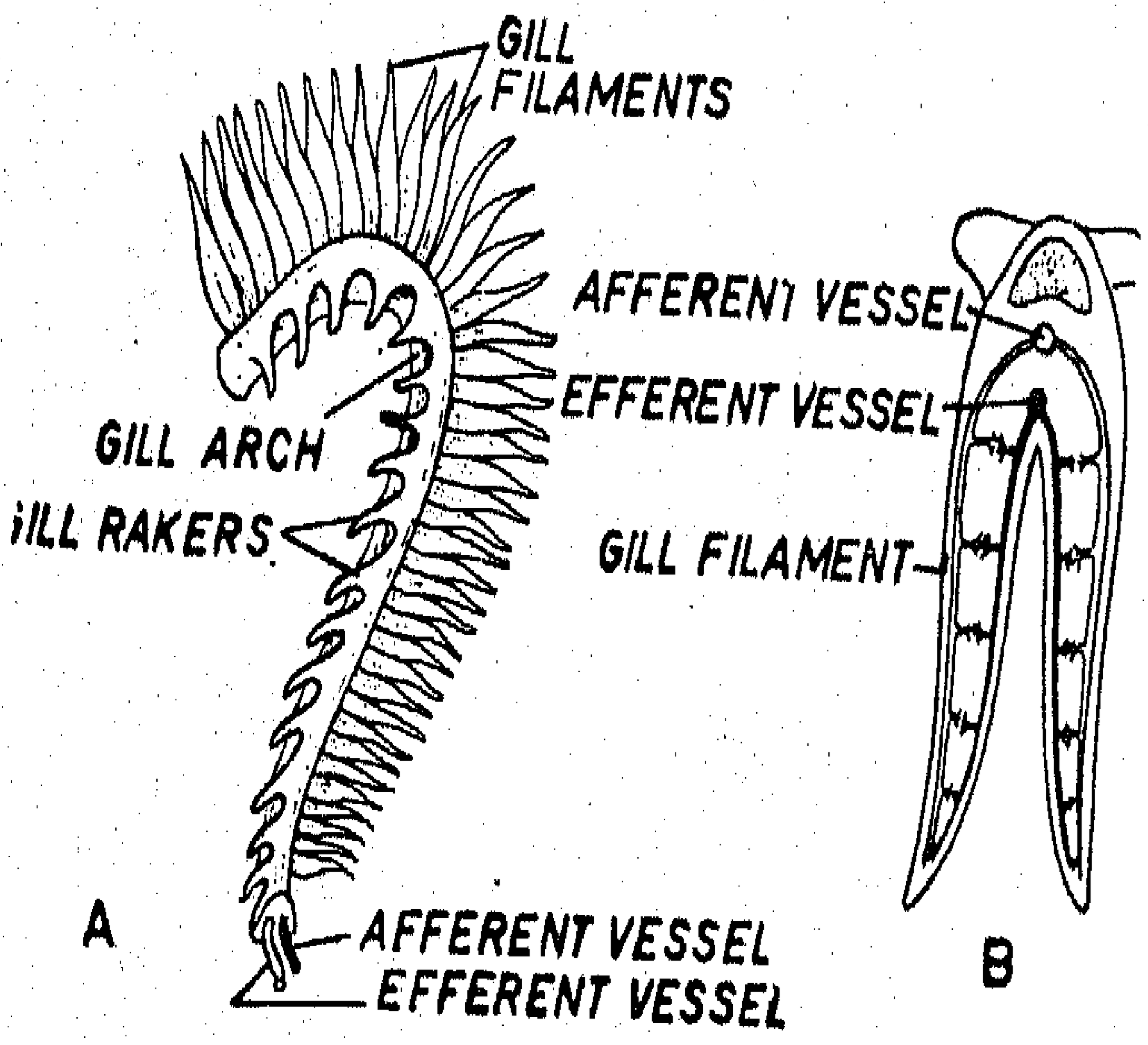


Fig. 131 A. *Fish—Gill* **B.** *Section of Gill*

Mechanism of Respiration

During inspiration, the mouth is open and the floor of the buccal cavity is lowered; water, therefore, enters the buccal cavity. (Fig. 130B) Now the mouth is closed, floor of the buccal cavity is raised, and water is forced from the buccal cavity into the pharynx, and ultimately through the gill slits to the outside. By this rhythmic raising and lowering of the floor of the buccal cavity, a constant water current is maintained, which passes through the mouth, the buccal cavity, and the pharynx, and goes outside by way of gill slits. The exchange of gases takes place through the semi-permeable walls of the gill filaments, so that O_2 of the water diffuses into the blood and CO_2 from the blood diffuses out into the water. Hence the water leaving the pharynx is full of CO_2.

Respiratory System in Cockroach

The cockroach is an insect. In insects, respiration is carried out through an elaborate system of tubes called *tracheae* and their anastamosing branches called *tracheoles* (Fig. 132). Tracheal tubes are formed by the invagination of the ectoderm. The tracheal tubes (Fig. 134) are internally supported by a spiral thickening of a substance called the *chitin*. This thickening prevents the trachea from collapsing. The main tracheae divide and subdivide till they form minute branches called the *tracheoles*. Each cell of the body is provided with a tracheolar branch. Chitinous thickening is absent in the tracheole. The main tracheal

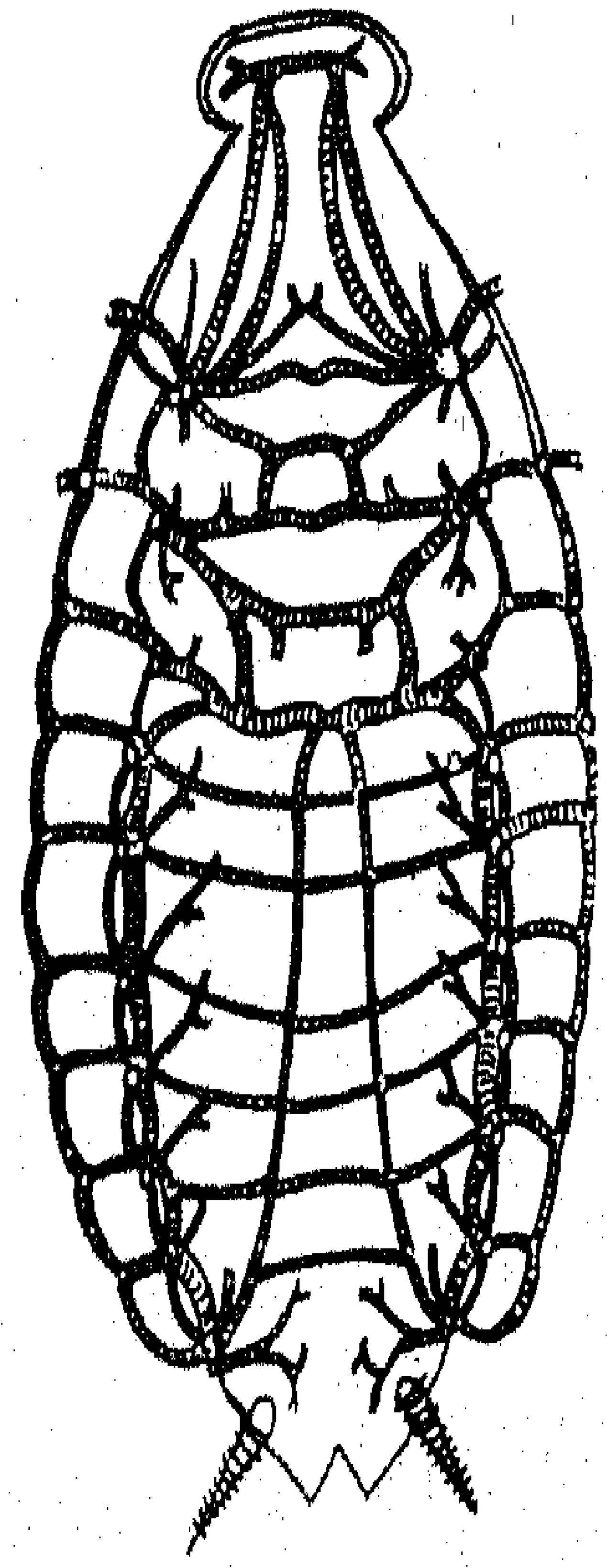


Fig. 132. *Cockroach—Tracheal System*

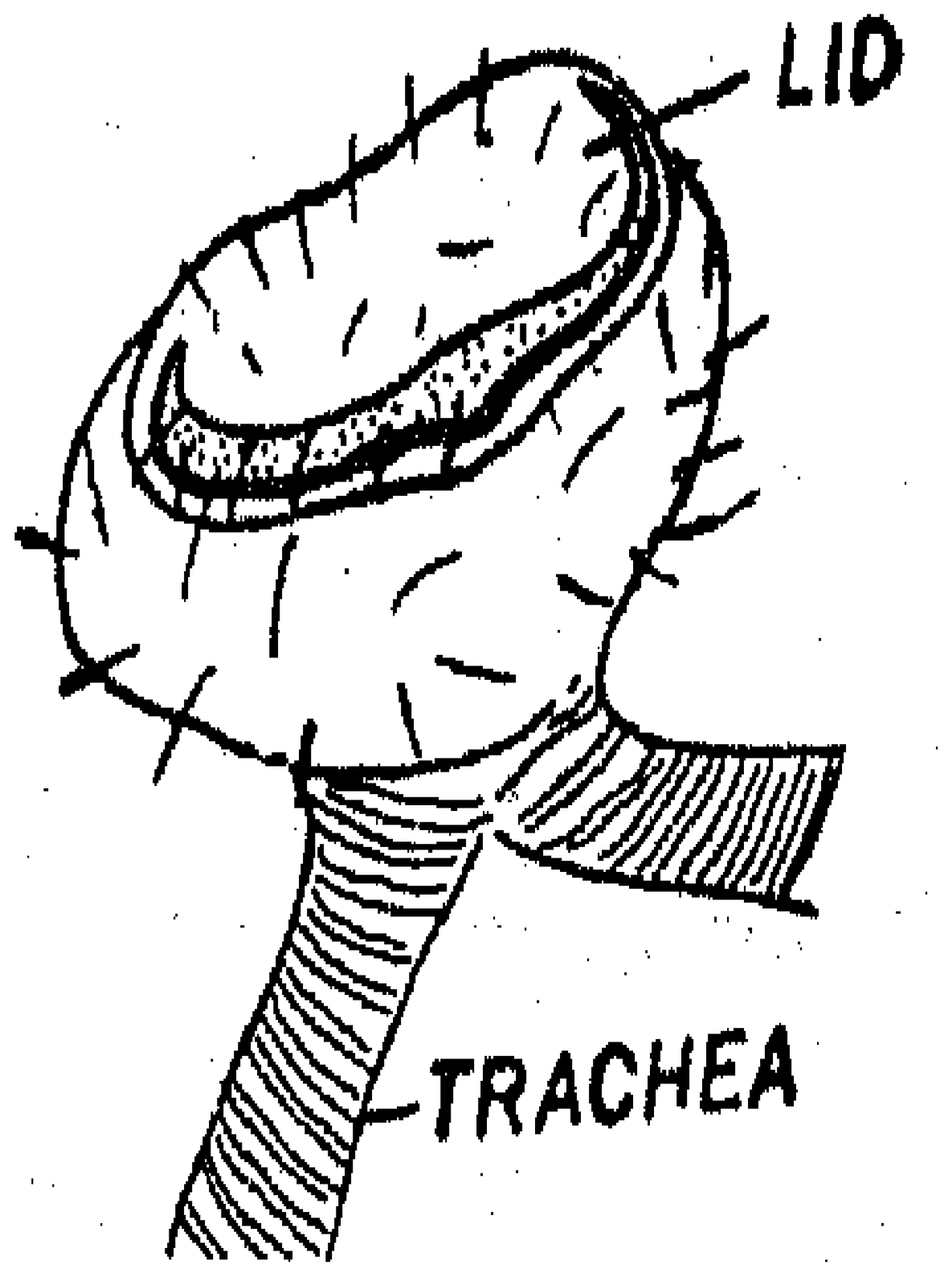


Fig. 133. *Thoracic Spiraticle*

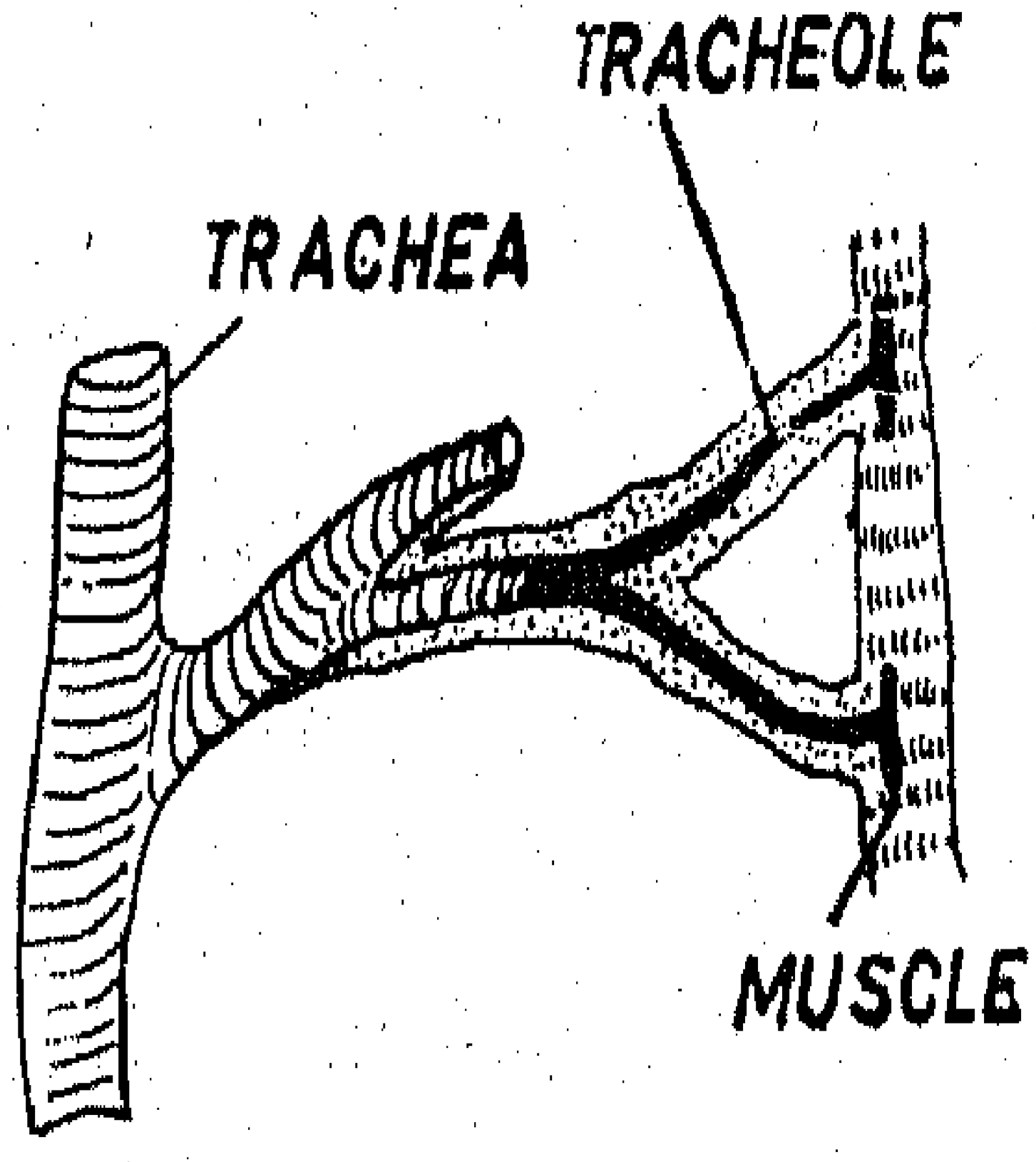


Fig. 134. *Trachea and Tracheole*

tubes communicate with the outside through ten pairs of openings called the *spiracles* or stigmata, which are situated at the sides of the body and are segmentally arranged. Two pairs are present in the thorax and eight pairs are present in the abdomen. The spiracles (Fig. 133) are supported by strong, chitinous walls, which are provided with fine bristles. The air enters the tracheal system through the spiracles, and is taken directly to the cells, where the gaseous exchange takes place. Due to this direct supply of air to each cell of the body, there is no necessity of a respiratory pigment to pick up and convey the oxygen. The blood is colourless by reason of the absence of the respiratory pigment, and it has lost its respiratory function.

The respiratory movements are brought about by the alternate contraction and expansion of the abdominal wall. Running from the dorsal tergum to the ventral sternum in each segment are the *tergo-sternal* muscles. The contraction and relaxation of these muscles bring about the contraction aud expansion of the body cavity. On expansion, the air is drawn into the tracheal system through the spiracles ; and on contraction the foul air is thrown out. The presence of a large number of spiracle ensures a regular supply of air, even if some of the spiracles get blocked.

Here it may be observed that there is no external respiration because of the total absence of a definite respiratory organ.

SUMMARY

1. Respiration is a biochemical process in which energy locked in the food is released in the form of chemical energy.
2. Lungs are the essential organs of respiration where exchange of gases take place.
3. The diaphragm plays a major role in bringing about respiration.
4. In birds the lungs are small and slightly distensible.
5. The air sacs are situated outside the lungs. They are 9 in number.

6. The air sacs serve as reservoirs of air. They give buoyancy and also help in maintaining balance of the body.
7. Inspiration in bird is a passive process while expiration is an active process.
8. Respiration in frog is of these type namely (a) cutaneous (b) buccal and (c) Pulmonary.
9. Fish can respire only in water, gills being the respiratory organs.
10. In cockroach respiration is carried out through trachiae.
11. The respiratory movement is brought about by the contraction and expansion of the abdominal wall.
12. Air in the case of Cockroach is directly supplied to each cell of the body.

BIOLOGICAL WORDS

Respiration
Trachea
Bronchus
Olveoli
Cutaneous respiration
Gill
Spiracle
Operculum

QUESTIONS

1. What is respiration? Describe the respiratory organs and mechanism of respiration in Man.
2. Write short notes on:—
   (a) Air Sacs. (b) Caryngoetracheal chamber (c) Spiracle (d) Gill of fish
3. Describe :—
   (a) Mechanism of pulmonary respiration in frog (b). Mechanism of respiration in fish.
4. What is respiration ? Describe different types of respiration in frog.
5. Describe the respiratory systems of Cockroach.

11

Excretion

Excretion. During the process of tissue metabolism, certain waste products such as urea, uric acid, creatinin, carbon dioxide and water are formed. These get into the circulatory system. Unless these are eliminated, they produce harmful effects on the body. This process of elimination of the metabolic waste products is known as excretion.

Carbon dioxide and some quantity of water vapour are eliminated through the surface of the respiratory organs. A certain amount of salts and water is also removed by the skin in mammals. The kidneys, lungs and the skin (in mammals) are the organs of excretion.

In vertebrates, the urinary or excretory system is in close association with the genital, or reproductive system. This association is more marked in males, in whom some of the ducts serve to convey both the genital and excretory products. Thus a common term, *Urino-genital system,* is in use to describe the two systems together.

Excretory System in man

In human beings, the excretory system consists of a pair of kidneys, a pair of ureters and the urinary bladder. (Fig. 135). The kidneys are the chief organs of excretion. They are two, dark red, bean-shaped structures situated in the abdominal cavity, one on each side of the vertebral column. Each kidney is about 4" long and 2" broad. The left kidney in man is placed slightly higher than the right one. On the inner margin which faces the vertebral column, each kidney has a depression, called *hilus.* Near the hilus, a renal artery enters and a renal vein comes out of the kidney. The ureter also comes out of the kidney from this region.

The kidneys are mainly responsible for the extraction of metabolic wastes from the blood and their elimination as urine

The ureters are two narrow tubes, each about 12" long, arising from the hilus. They lead downwards to the urinary bladder in the pelvic cavity. The urine formed in the kidneys is taken to the urinary bladder by the ureters, where it is temporarily stored.

The urinary bladder is a muscular bag lying in the pelvic cavity. It acts as a temporary reservoir for urine. Arising from the lower portion of the urinary bladder is a median duct, called *urethra.* The opening of the bladder into the urethra is guarded by a sphincter muscle. In males, it runs through the penis and opens at its tip. In males, the reproductive ducts also open into the urethra. Thus the urethra forms a common passage for urine as well as the genital products. In females, the urethra is short and it opens slightly above the opening of the vagina; it has a separate opening. The urethra in females is exclusively excretory in function.

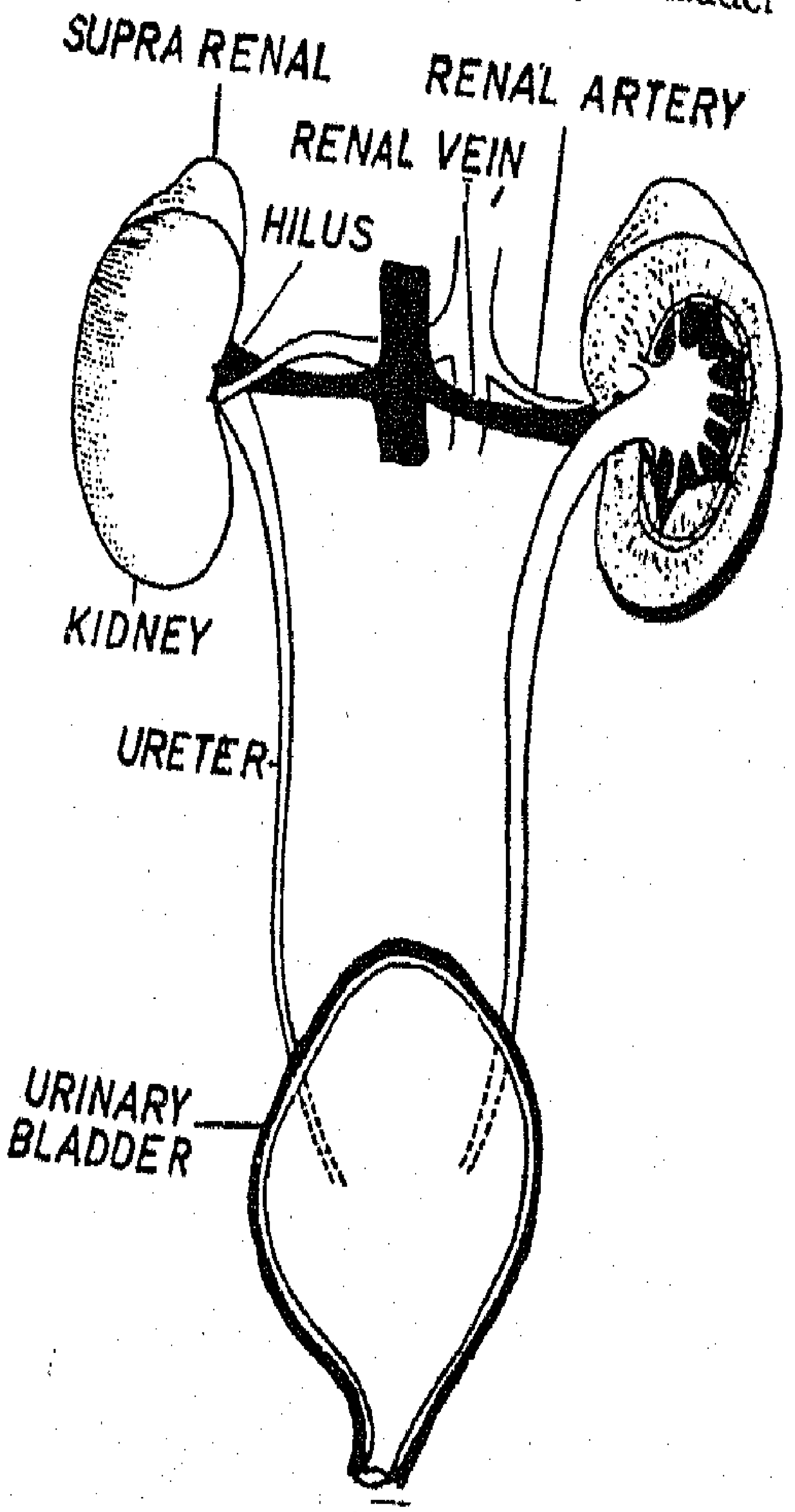


Fig. 135. *Human—Excretory System*

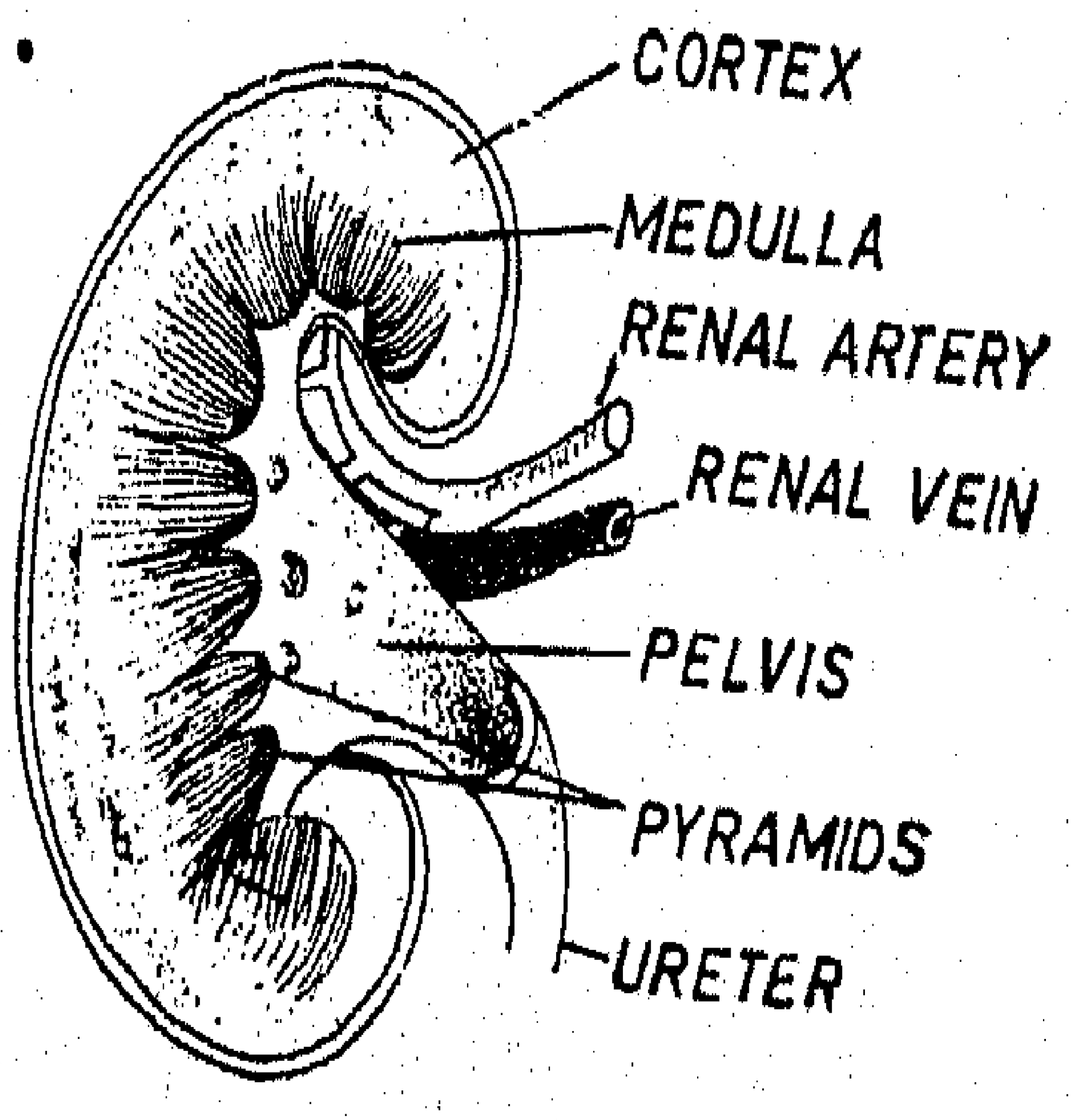


Fig. 136. *V. S. of Human Kidney*

Internal Structure of the Kidney

A longitudinal section of the kidney reveals an outer *cortex* and an inner *medulla.* (Fig. 136). The medullary region towards the side of the hilus is produced into about 12 cone shaped *pyramids.* These pyramids open into a triangular space, the *pelvis*, which is continued further into the ureter.

The substance of the kidney is made up of a large number of coiled microscopic tubules called *Uriniferous tubules* or *nephrons*,

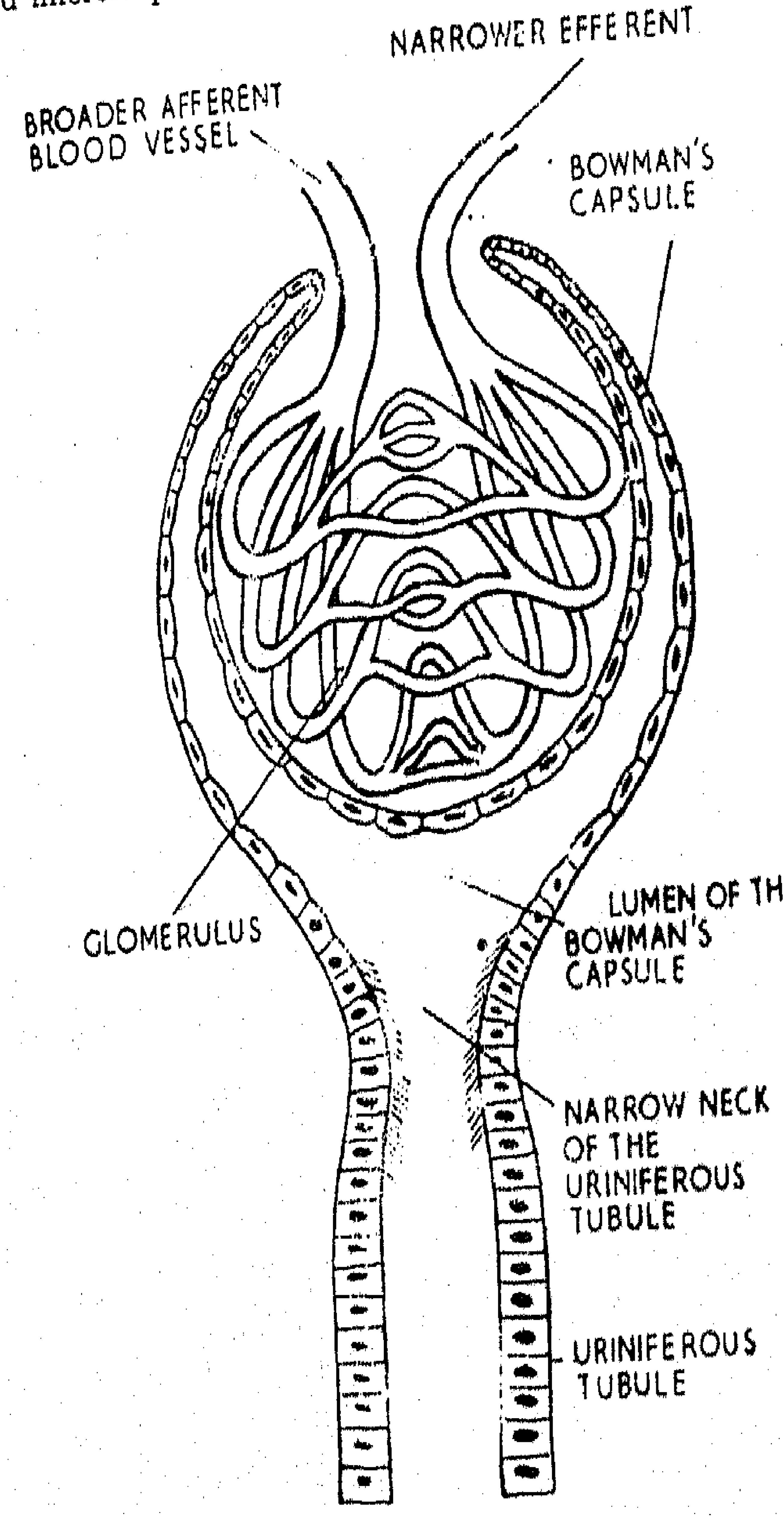

NARROWER EFFERENT
BROADER AFFERENT BLOOD VESSEL
BOWMAN'S CAPSULE
GLOMERULUS
LUMEN OF THE BOWMAN'S CAPSULE
NARROW NECK OF THE URINIFEROUS TUBULE
URINIFEROUS TUBULE

Fig. 137. *Malpighian Corpuscle*

which are closely packed together by connective tissues. The nephrons are the units of excretion.

MALPIGHIAN BODY { BOWMAN'S CAPSULE
GLOMERULUS

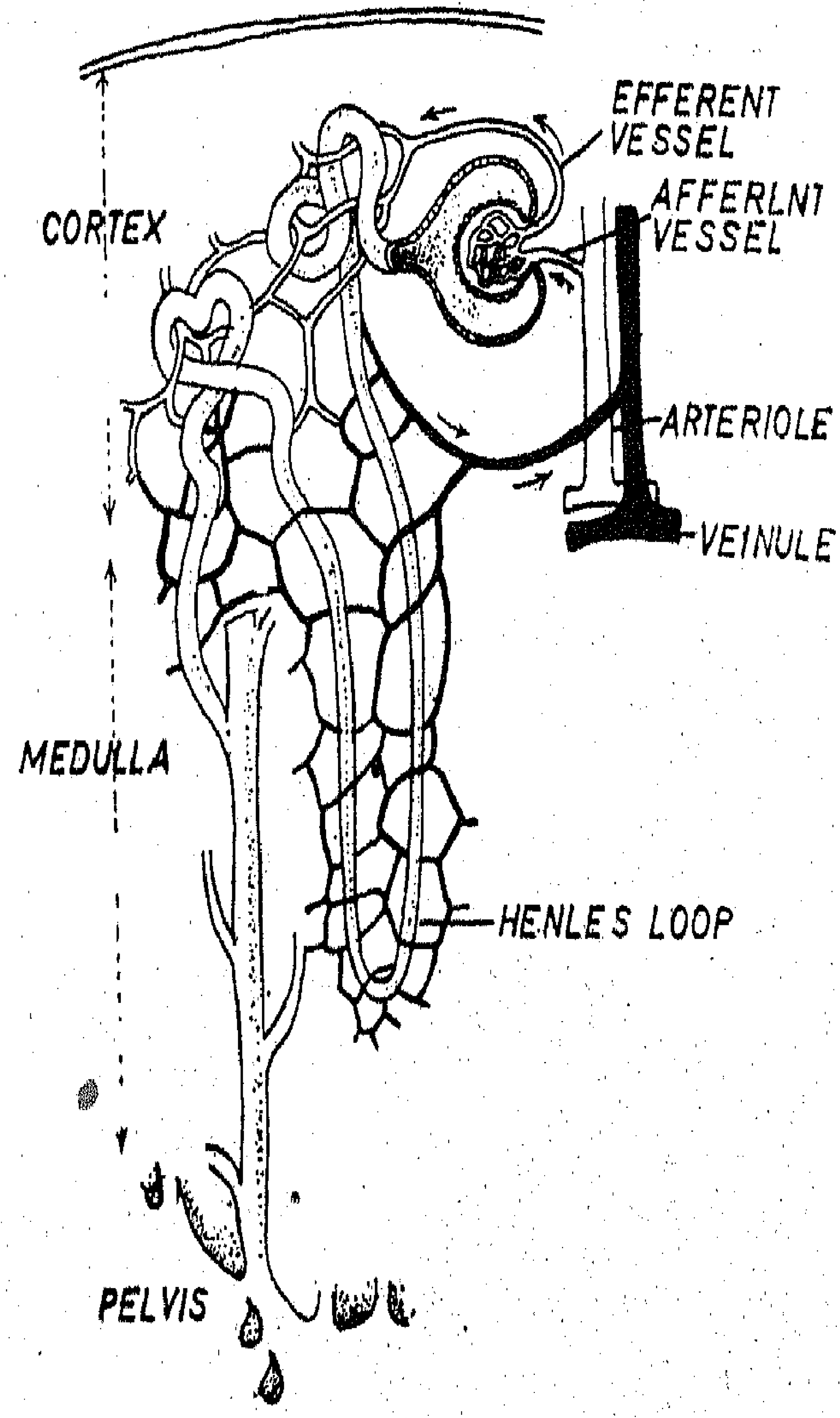


Fig. 138. *Uriniferous tubule*

The blind end of each uriniferous tubule is enlarged and modified to form a cup-shaped, double-layered structure called the *Bowman's capsule.* (Fig. 137). This portion lies in the cortex and is lined with flattened epithelial cells. Inside the depression of the Bowman's capsule is a knot of blood capillaries called *glomerulus.*

The Bowman's capsule, along with its glomerulus, is referred to as *Malpighian body* or corpuscle (renal corpuscle). The renal artery, which enters the kidney at the hilus, divides and redivides into a large number of finer branches called arterioles. Entering into each Bowman's capsule is a renal arteriole called *afferent renal arteriole.* This branch breaks up into a capillary network, which once again unite and reunite to form another vessel called the *efferent renal arteriole.* The efferent vessel comes out of the Bowman's capsule through the same opening that the efferent vessel has entered. The network formed by these blood vessels is the *glomerulus.*

The Bowman's capsule leads into a thin-walled, very much convoluted tubule by a short neck. This tubule is lined with cuboidal cells of glandular epithelium, which are ciliated at the neck region. This tubule runs a twisted course in the substance of the kidney, and ultimately opens into one of the collecting tubules. The collecting tubules, which receive such numerous other uriniferous tubules, open at the tip of the pyramids. The pyramids, in turn, open into the pelvis, which is continued down into the ureter.

Each uriniferous tubule (Fig. 138) shows the following three regions:

(1) A proximal convoluted tubule;
(2) A middle hairpin-shaped Henle's loop; and
(3) A distal convoluted tubule.

The efferent vessel, after leaving the Malpighian body, breaks up again into a second set of capillaries over the convoluted tubule. These capillaries then reunite to form a small venule. A number of such venules from different uriniferous tubules unite to form a renal vein, which comes out of the kidney and opens into the posterior vena cava.

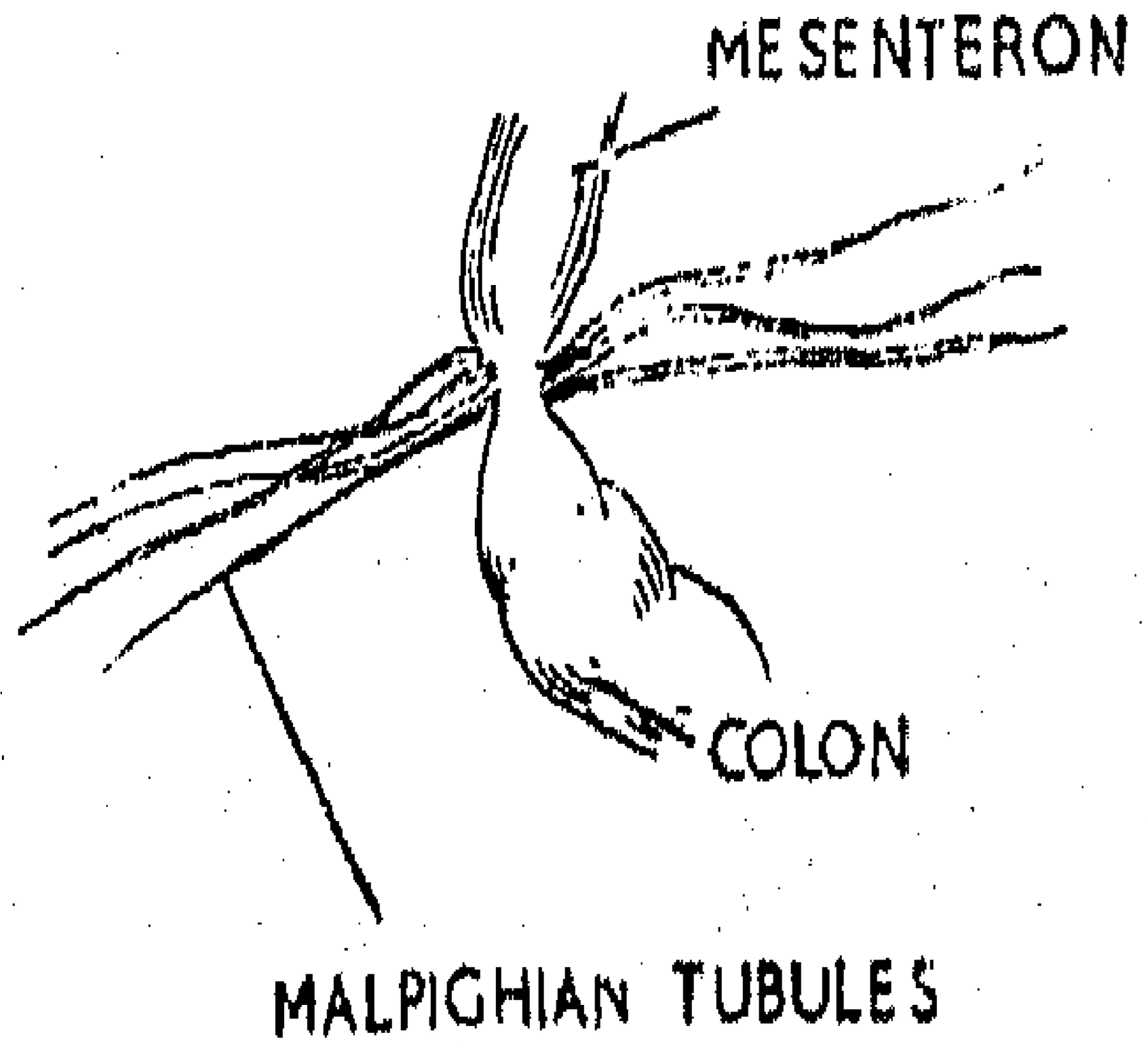


Fig. 139. *Malpighian tubules*

Process of Excretion

The blood, rich in metabolic waste matters, is brought to the kidneys through the renal arteries for their elimination. The Bowman's capsule acts like a filter. This filtration takes place through the thin lining of the glomerular capillaries and the inner semi-permeable membrane of the cup-shaped Bowman's capsule. The blood inside the glomerulus is under a great pressure, because more blood is brought into the glomerulus than is being taken away by the efferent blood vessel. This is due to the larger diameter of the efferent as compared to the smaller diameter of the efferent vessel. This filtration is referred to as *ultrafiltration.*

The glomerular filtrate, which is collected inside the cavity of the capsule, contains, along with waste matters, also useful substances like glucose, water, some mineral salts, etc. As the filtrate contains all the constituents of the plasma except proteins, it is known as *deproteinised plasma.* As this filtrate moves down the renal tubule, the useful materials are reabsorbed by its walls and given back to the blood circulating in the capillaries surrounding the tubule. This blood, deprived of its nitrogenous waste, is taken through the renal veins to the post-caval vein and then to the heart.

The liquid that is passing down the tubule of the nephron, after the reabsorption of the useful materials, is called urine. This drips down into the common collecting tubules and ultimately is collected at the pelvis to be evacuated to the urinary bladder through the ureters.

The urine contains nitrogenous waste products such as urea, uric acid, creatinine and certain inorganic salts.

The kidneys thus not only extract the nitrogenous and other waste products from the blood, but also reabsorb certain substances, including water, which are needed by the body. They help in regulating the composition of the blood and maintain the water balance in the tissues and cells. Therefore, the kidneys are also referred to as osmoregulatory organs.

Excretion in Invertebrates

Cockroach. The excretory organs of the cockroach are called *Malpighian tubules.* They are fine, thread-like, yellowish glandular tubules. (Fig. 139) They are about 60 to 80 in number, arranged in 6 to 8 groups at the junction of the midgut and the hindgut. They float in the haemocoele. They open at one end into the hindgut, and their free ends are blind. Their walls are thin and semi-permeable. They extract nitrogenous waste matters like urea, uric acid and urates from the surrounding blood present in the haemocoele and discharge them into the hindgut for disposal out of the body.

Earthworm. The excretory organs of the earthworm are called *Nephridia*. They are microscopic coiled tubular structures found almost in all the segments of the body. (Fig. 140).

Depending upon their location in the body, the are classified into the following three types.

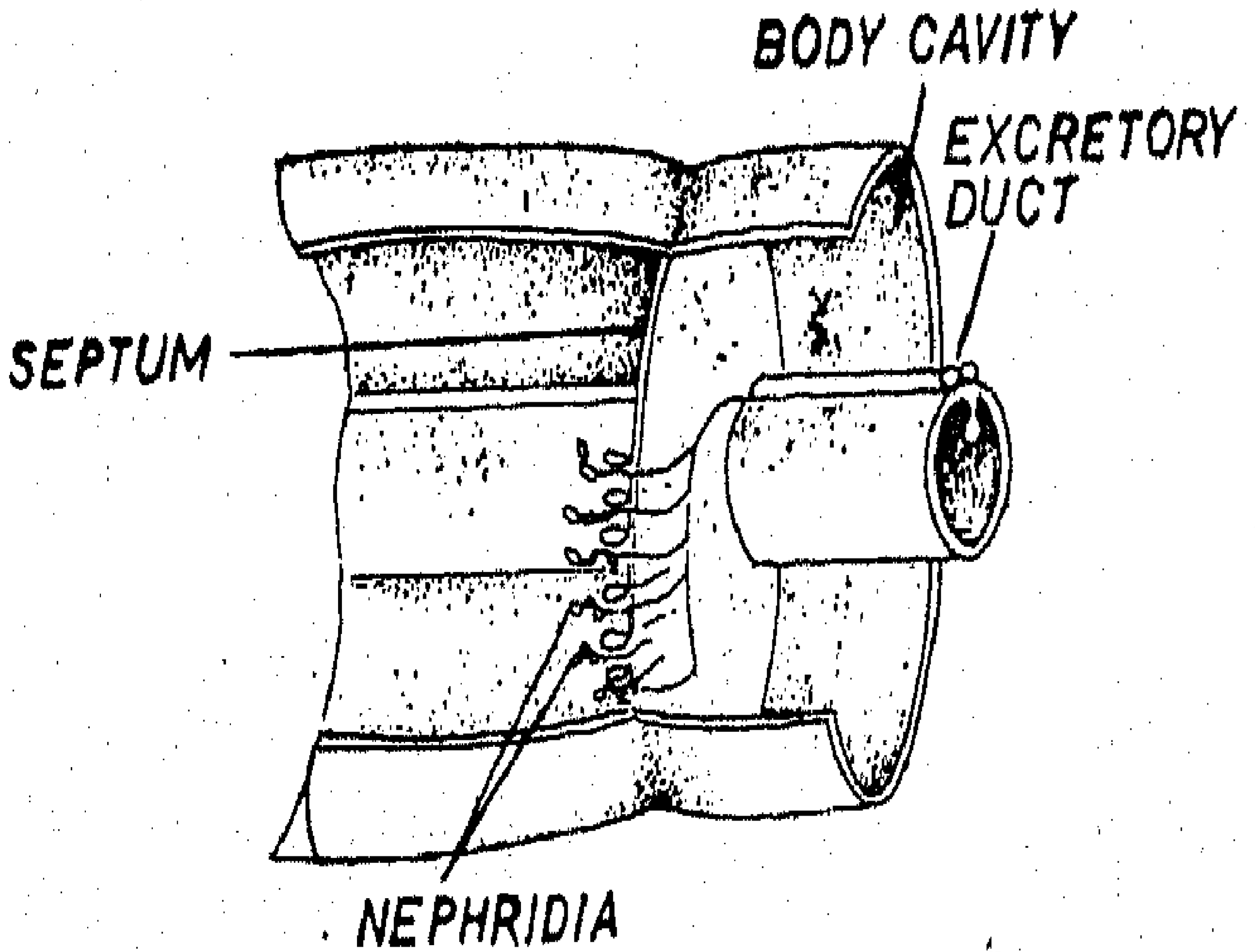


Fig. 140. *Nephridial System*

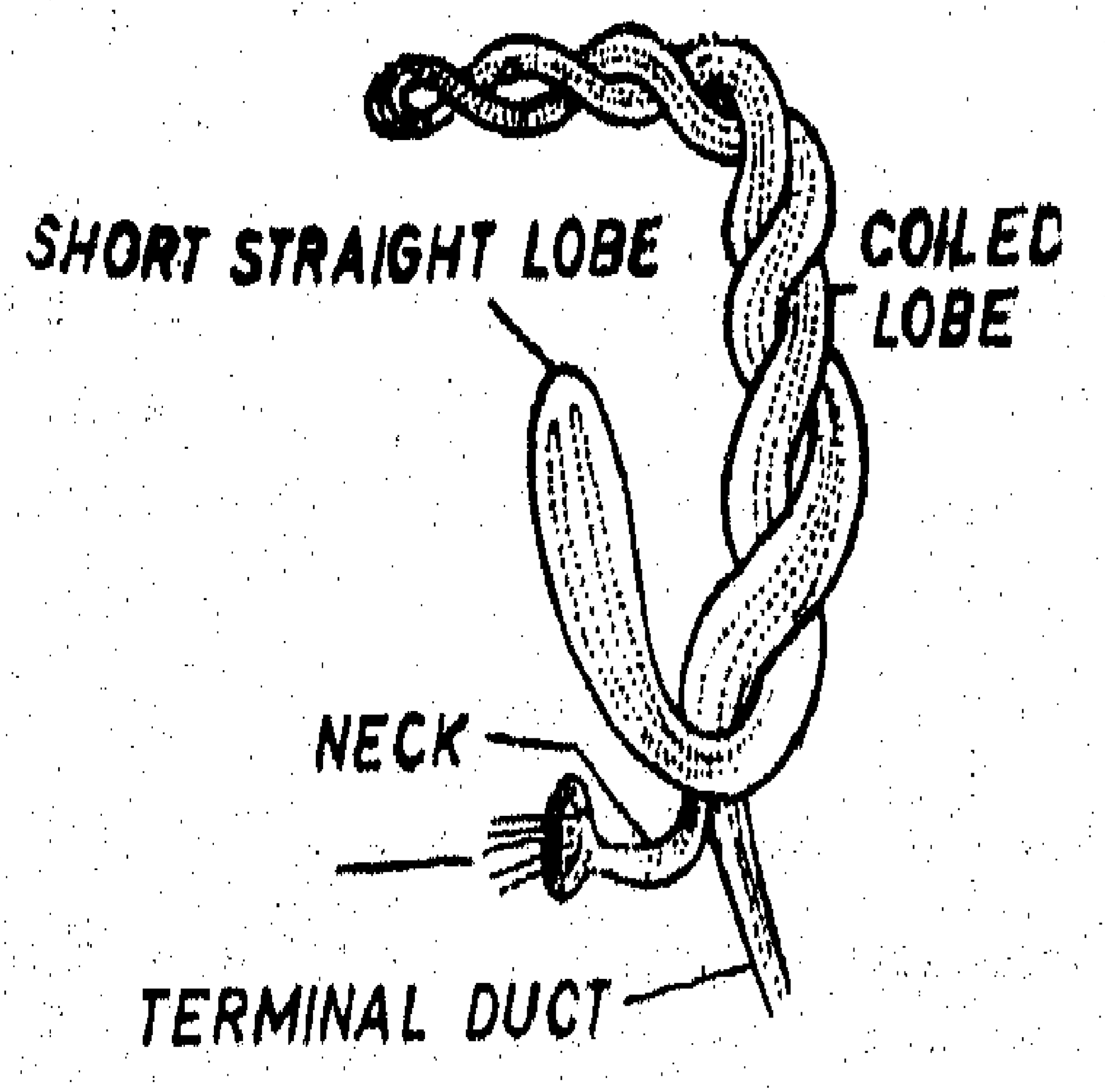


Fig. 141. *Septal Nephridium*

(i) Septal nephridia, present on the septa:

(ii) Pharyngeal nephridia, present at the pharyngeal region; and

(iii) Integumentary nephridia, found attached to the skin.

Septal nephridium is considered as a typical nephridium. (Fig. 141) It consists of

(1) **Nephrostome:** This is a funnel-shaped opening provided with cilia. It opens into the coelom.

(2) **Neck:** It is a short narrow tube which connects the ciliated funnel to the body of the nephridium.

(3) **Body:** This region is lined with glandular cells. It is divisible into a short straight lobe and a long spirally twisted loop. The semi-permeable wall of the twisted loop is vascular, being surrounded by a network of capillaries.

Terminal duct: It opens ultimately into the alimentary canal by a system of collecting excretory canals.

The coiled loop extracts waste matters from the blood, while the nephrostome drives them from the surrounding coelomic fluid. These nitrogenous waste matters are ultimately eliminated from the body.

Amoeba: In acellular animals like amoeba, there are no special excretory structures. Excretion is achieved through the general surface of the body by diffusion. The function of excretion is also performed by a structure called *contractile vacuole*. This vacuole is an excretory organelle, which appears at any point in the endoplasm as a clear space. By reason of the accumulation of metabolic wastes from the cytoplasm, it grows to certain size and then bursts open on the surface of the body, discharging its contents to the outside. This process is repeated over and over again. During this process, the contractile vacuole removes not only certain metaobolic waste materials from the body but also eliminates the excess of water continuously entering the body through the thin cell-membrane. Because its main function is to regulate the water content of the body, it is described as osmoregulatory in function.

SUMMARY

1. Excretion is the elimination of waste matter formed as a result of metabolism.
2. Kidneys are the chief organs of excretion.
3. In human males urethra forms a common passage for urine and spermatic fluid, while in females it is exclusively excretory in function.
4. The uriniferous tubules or nephrons are the units of excretion.
5. In cockroach malpighian tubules are the excretory organs.

In earthworm the nephridia are the excretory organs.

BIOLOGICAL WORDS

Excretion
Nephron
Glomerulus
Urethra
Ureter
Bowman's Capsule
Malpighian tubules
Nephridium.

QUESTIONS

1. What is excretion? Describe the organs of excretion and mechanism of excretion in Man.
2. Write short notes on:—
   (1)Malpighian body, (2) Malpighian tubules, (3) Contractile Vacuole (4) Nephridium
3. Draw neat labelled sketches of:—
   (a) Excretory system of Man. (b) Uriniferous tubule, (c) Nephridium

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Reproduction 12

The most important characteristic feature of a living organism is its ability to reproduce individuals of its own kind. This process is called reproduction. But for this process, life would have ceased to exist.

There are two methods by which animals reproduce. (1) Sexual reproduction; (2) Asexual reproduction.

Sexual Reproduction. This process involves two sexes, a male and a female. The male possesses the reproductive organ known as the testis, while the female possesses the ovary. These two organs are specialised glands, which produce sex cells known as the gametes. The male gamete is the *sperm* and the female gamete is the *ovum.* The main feature of sexual reproduction lies in the union of these two dissimilar gametes by a process known as fertilisation. The fertilised ovum or *zygote,* by further development, gives rise to a new individual.

Asexual Reproduction. It is a process of reproduction wherein new individuals are produced without the help of the gametes. Normally, it is done either by a process of budding or by the division of the body or cutting of a part of the body which, on getting detached, develops into a complete, independent individual.

Human Reproductive System

Human beings are unisexual, i.e. the sexes are separate. The sexes can be distinguished by certain external features called secondry sexual characteristics.

Male Reproduce Organs. The important male genital organs are the testes (singular testis), which are oval bodies about the size of a pigeon's egg. Except the mammals, in all other vertebrates the testes normally lie within the abdominal cavity. In mammals, they develop first in the abdomen, but just before birth they descend into a bag-like structure, the scrotum or scrotal sac, lying outside body. (Figs. 142 & 143) The scrotum in man is divided into

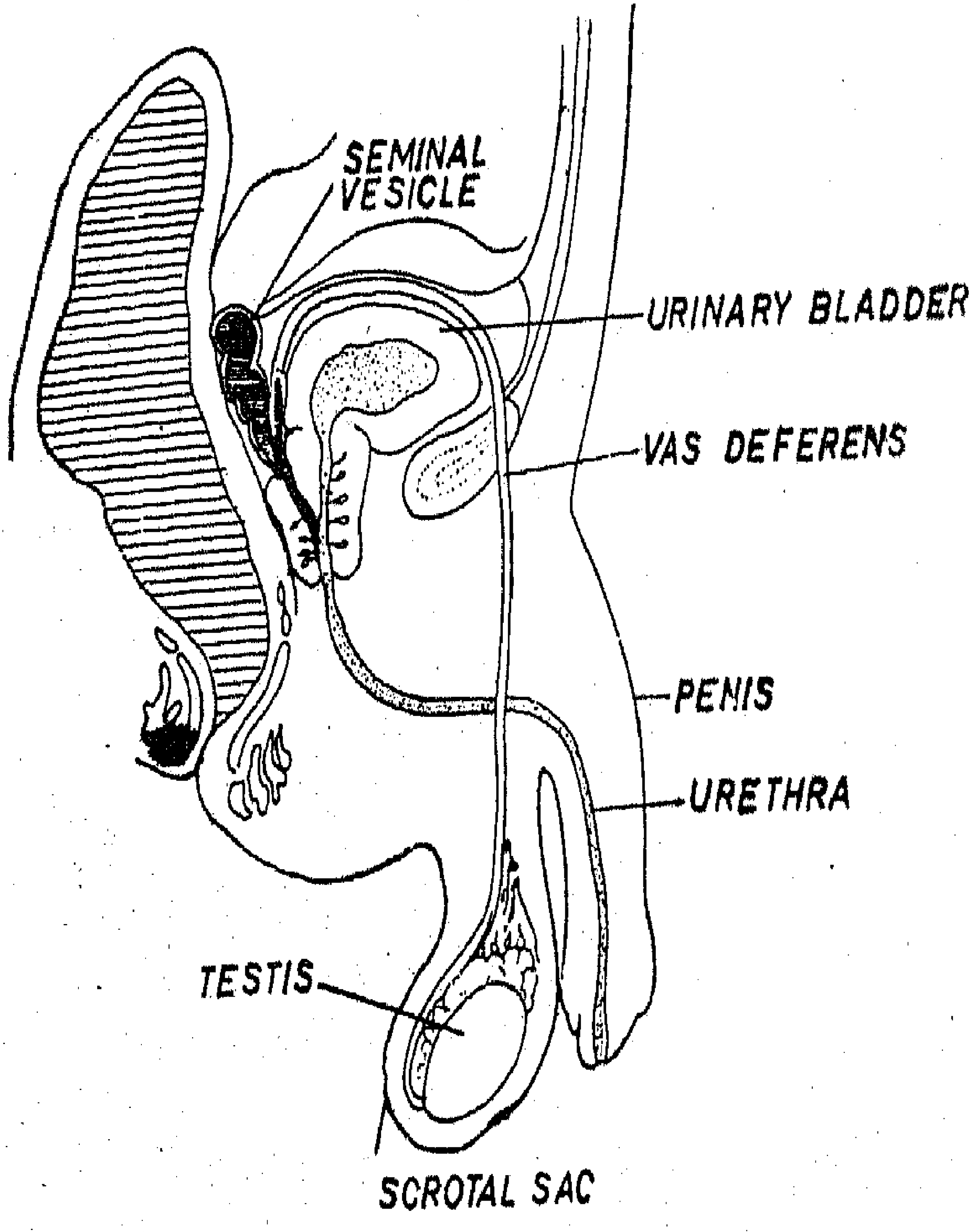


Fig. 142. *Human Male Reproductive System (Lateral View)*

two chambers by a septum, and in each lies a single testis. The reason why testes are suspended out of the body cavity is that, in most of the mammals, the sperms cannot develop at that high temperature found inside the abdominal cavity.

Each testis is made up of a large number of closely-packed, very much-coiled tubules, the *seminiferous tubules.* These tubules are lined with germinal epithelium. The cells of the germinal epithelium produce the male gametes called spermatozoa or sperms. These seminiferous tubules open by fine ductules into a long, slender, much-coiled tube, the *epididymis.* This epididymis forms a compact mass and lies on the surface of the testis. This epididymis

becomes continuous with another duct, the *vas deferens.* The two vasa-deferentia of both the testes pass upwards and, coming out of the scrotum, enter the abdominal cavity; then they open into the urethra at the neck region of the urinary bladder.

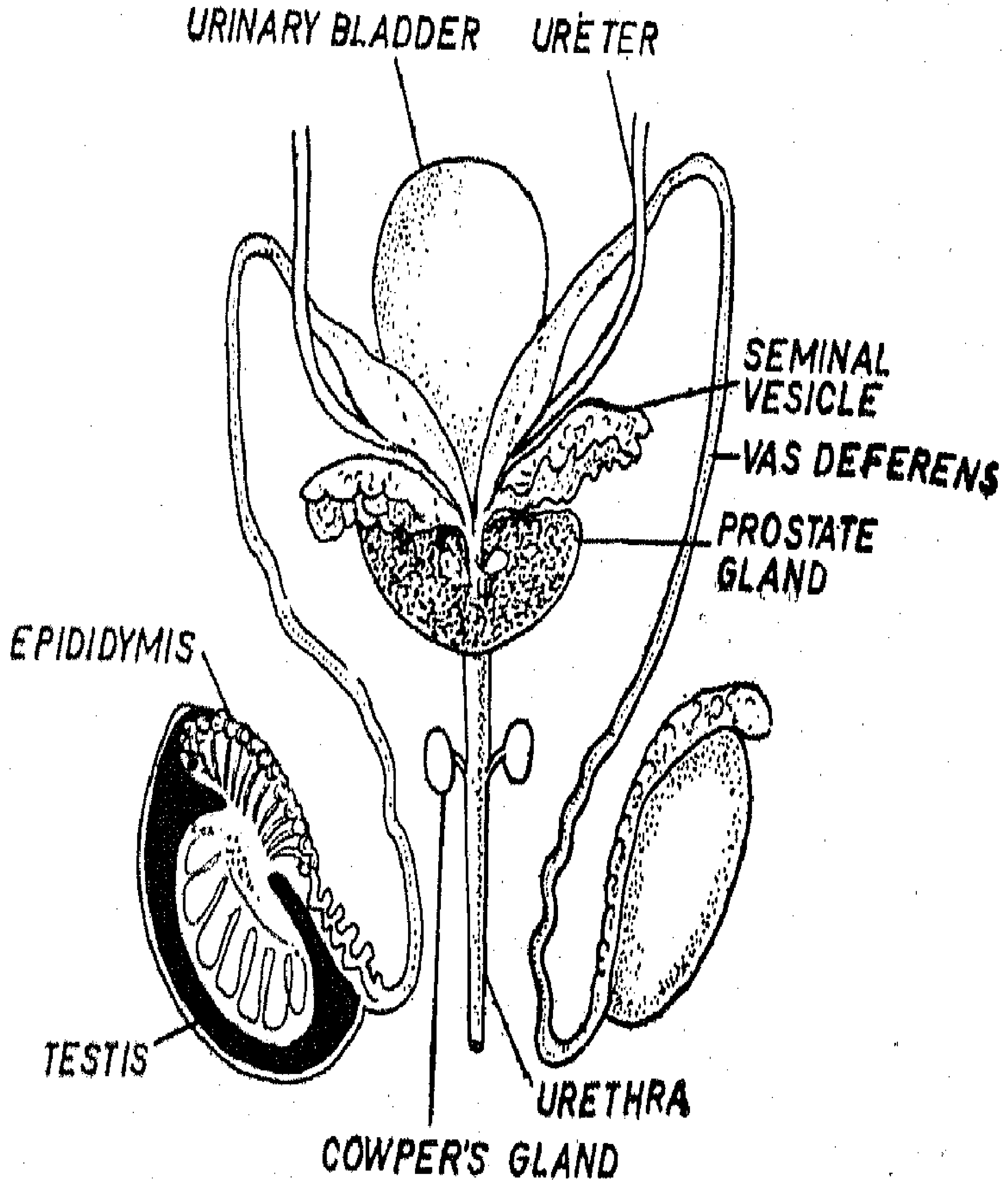


Fig. 143. *Human Male Reproductive System (Front View)*

Just before the vasa deferentia open into the urethra, each one receives a duct from a glandular sac, the *seminal vesicle.* There is a pair of seminal vesicles, which lie at the base of the urinary bladder. The vas deferens, after receiving the duct from the seminal vesicle, is known as the *ejaculatory duct.* These vesicles secrete a viscid fluid. This secretion, mixed with the spermatozoa, is called *seminal fluid* or *semen.* The sperms become more active in the secretion of the seminal vesicles. The urethra or urino-genital duct in the male runs through a muscular organ, the *penis,* and opens at its tip. The penis is the copulatory organ, which is used to transmit or pass the seminal fluid into the vagina of the female during copulation. It is provided with a mass of erectil muscles. The terminal portion of the penis is the glans. is covered by a loose fold of skin called the prepuce.

Surrounding the neck region of the urethra is a pear-shaped prostate gland, which secretes a fluid. Cowper's glands are a pair of glands of the size of a pea lying at the sides of the urethra Their secretion is a clear viscid fluid, which serves as a lubricant.

Female Reproductive Organs. The ovaries are a pair of essential genital organs of the female (Fig. 144). They are almond-shaped, pinkish bodies found in the pelvic cavity, and are attached by ligaments to the uterus or womb. Each ovary consists of a central portion, the medulla, and an outer region, the cortex.

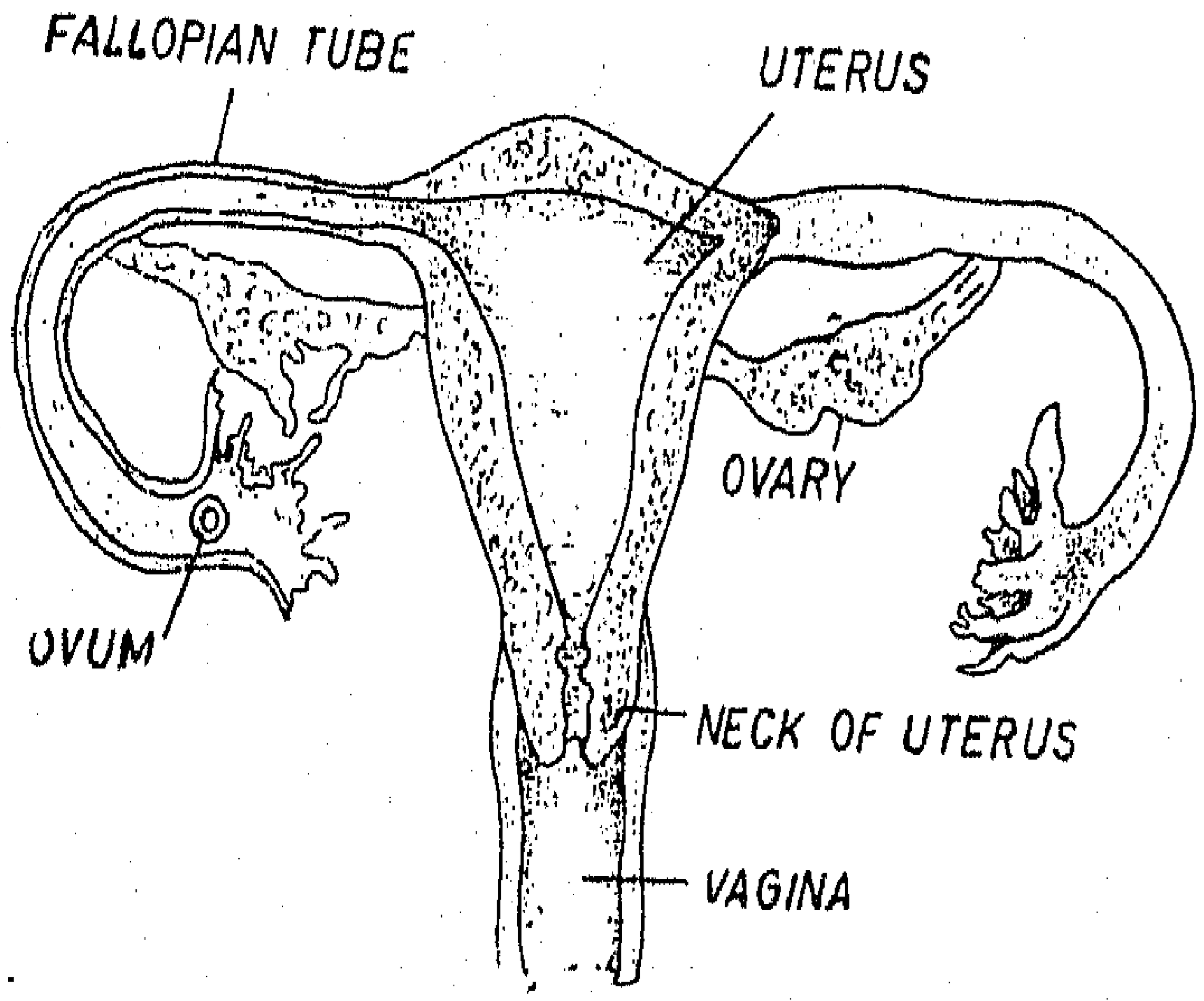


Fig. 144. *Human Female Reproductive System*

The cortex consists of a large number of groups of developing cells called the Graafian *follicles.* Found within each follicle is a developing ovum. Along with the growth of the ova, the follicles also enlarge and protrude on the surface of the ovary. Ultimately, a rupture of the follicle releases the mature ovum.

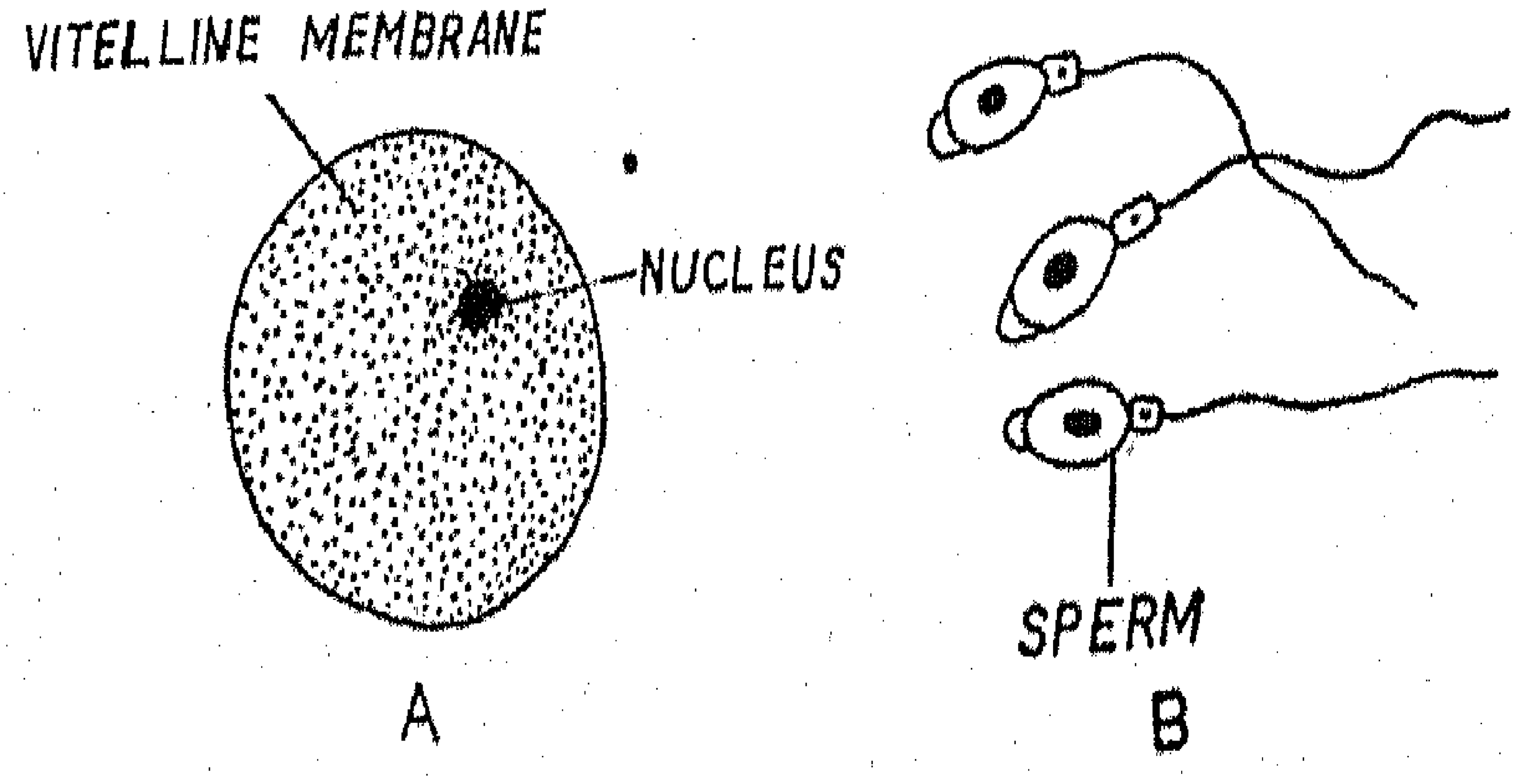
Found close to each ovary is the expanded funnel-shaped opening (with fringed margins) of a slender muscular duct, the utering tube or the *fallopian tube* (which is known as oviduct in other animals). The two fallopian tubes converge inwards and open at the corners of a highly muscular pear-shaped organ, the uterus or womb. The ovum discharged from the ovary is transmitted through the fallopian tubes to the uterus for further development.

The uterus or womb is a single pear-shaped, thick-walled muscular organ, lying in the pelvic region in between the urinary bladder in front and the rectum behind. It is in this region that the fertilised ovum undergoes development into an embryo and is nourished into a young one. During pregnancy, the uterus is stretched and enlarged considerably by the developing young one. It has an expanded upper body region which receives the fallopian tubes and a narrow lower portion, the cervix. The cervix opens into another highly distensible muscular tube or canal, the *vagina.* The vagina receives the copulatory organ, the penis of the male, during sexual union or copulation. The vagina, in turn, opens to the outside by a vertical cleft or vestibule, which is bounded on either side by two longitudinal fleshy folds. The outer and larger folds are the *labia majora* and the inner smaller ones are the *labia minora.*

In females, unlike in males, the reproductive and urinary tracts open separately to the outside. The opening of the urethra is slightly anterior to that of the vagina.

Sex Cells (**Gametes**)

(a) **Ovum.** The ovum is a minute single-celled structure. It is spherical, with a nucleus (germinal vesicle) and cytoplasm, surrounded by a thin membrane called the *vitelline membrane.* (Fig. 145-A). The cytoplasm contains droplets of yolk which serves as a reserve food matter for the developing zygote. Unlike the spermatozoa the ovum is passive and stationary.



Ovum *Sperm*

Fig. 145. *Human gametes*

(b) **Spermatozoa.** They are microscopic and very much smaller in size when compared to the ovum. They are produced in very large number. (Fig. 145-B). Each sperm is made up of (i) an oval head, containing a nucleus; (ii) a short neck or middle piece; and (iii) a long and slender vibratile cytoplasmic tail. The sperms are active and are able to move with the help of their motile tail.

Ovulation. The process of liberation of the ovum from the ovary is called *ovulation.* In the human female, ovulation starts from the day of puberty (which is attained at the age of about 13-15) till the menopause (which is reached about the age of 45). Normally, one ovum is liberated, once in every 28 days. However, during pregnancy, due to certain hormonal secretions, ovulation ceases. Normally, one ovum is liberated alternately from each ovary at a time. However, rarely two or more ova may also be liberated at a time.

Fertilisation. During the process of sexual union or copulation, the sperms are deposited in the vagina of the female. These sperms travel upwards and find their way into the uterus, and then the fallopian tubes. In the neck of the fallopian tubes, the union of the sperm with the ovum takes place. This union is called fertilisation, during which the sperm nucleus fuses with the nucleus of the ovum. The fertilised ovum is now called the zygote, and its nucleus is known as the zygote nucleus. Fertilisation gives the necessary stimulus for the further development of the egg. Only one sperm can penetrate and fertilise the ovum.

If the ovum fails to get fertilised in the fallopian tube, it starts decomposing during its passage down into the uterus. From the uterus, it is removed to the outside at a later stage. About a fortnight after ovulation (and if there is no fertilisation), the disintegration of thethinner lining of the uterus, along with haemorrhage, takes place. This discharge is known as *menstruation.* This takes place regularly every month and a new lining develops in the uterus once again, thus preparing the uterus to receive another ovum during a subsequent ovulation.

If, however, the ovum is fertilised, the zygote descends into the uterus and gets implanted or fixed in the vascular wall of the uterus, where further development towards the formation of the embryo and the young one takes place. At this stage, certain hormones are secreted by a special mass of cells in the ovary (corpus luteum), which prevent the menstruation till the full development of the young one is fulfilled. During this period of development, further ovulation is also prevented, and the embryo establishes an intimate contact with the vascular uterine wall through the *placenta.* (Fig. 146). This placenta is a spongy, disc-like vascular structure. The embryo is connected with the placenta through a placental cord.

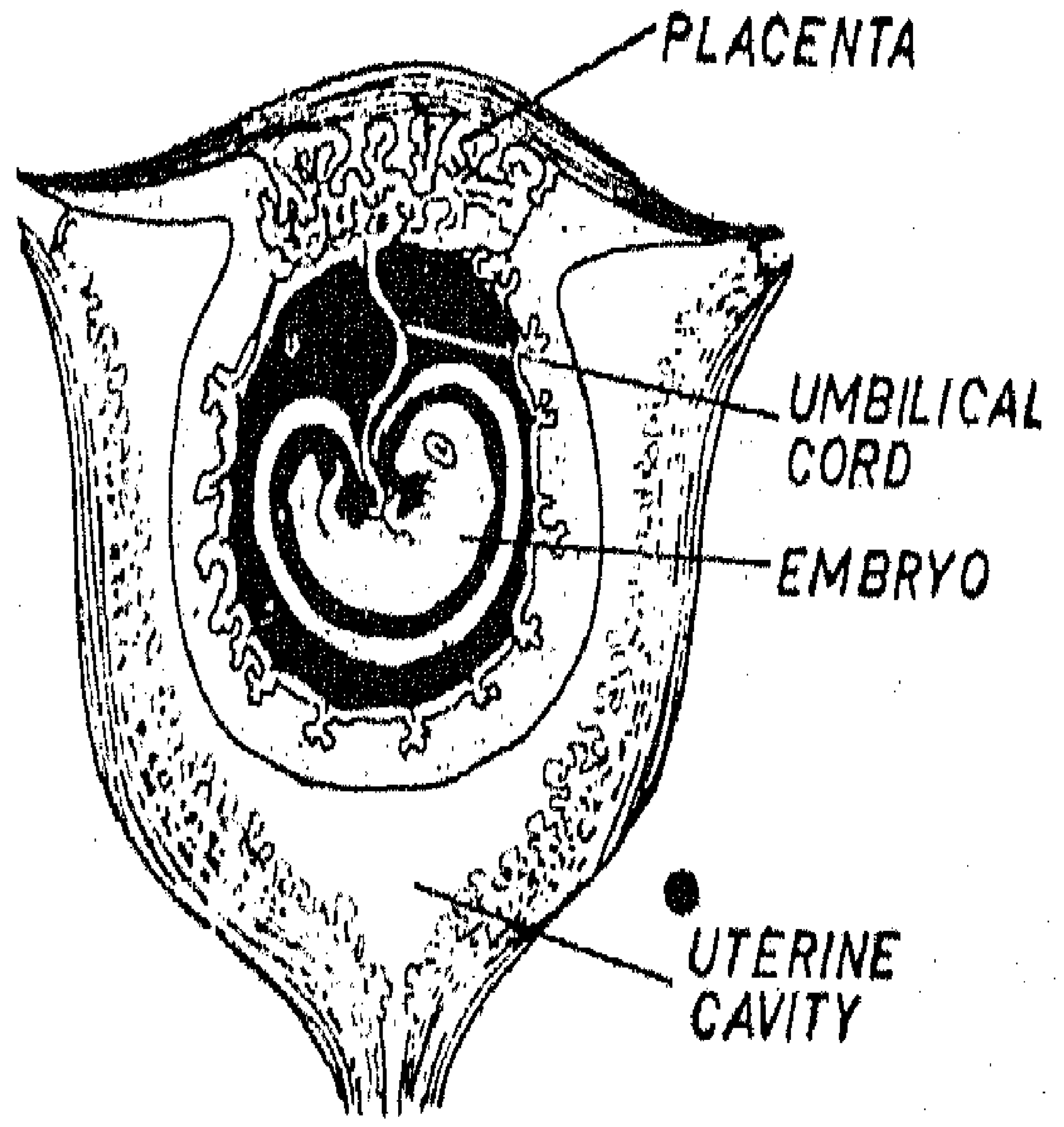


Fig. 146. *Human: Embryo in the Uterus*

The placenta mainly serves the function of absorbing nourishment from the vascular uterine wall, which is conducted to the embryo through the blood vessels in the placental cord. It also serves the function of respiration and excretion for the embryo.

The period required for the full development is known as *gestation period.* In human beings this period is about 9 months. Like all other mammals, human beings are called *viviparous* because they give birth to young ones.

Reproductive System of rat.

In the male, there is a pair of testes, each one in a separate scrotal sac. The epididymis is attached to the dorsal surface of the testis. (Fig. 147). The two vasa deferentia open into the urethra. There is a pair of seminal vesicles, which are very prominent, curved and sacculated. Two prostate glands lie one on either side of the urethra at the neck region, and open into it. There is also a pair of Cowper's glands opening into the urethra, which runs through the penis and opens at its tip.

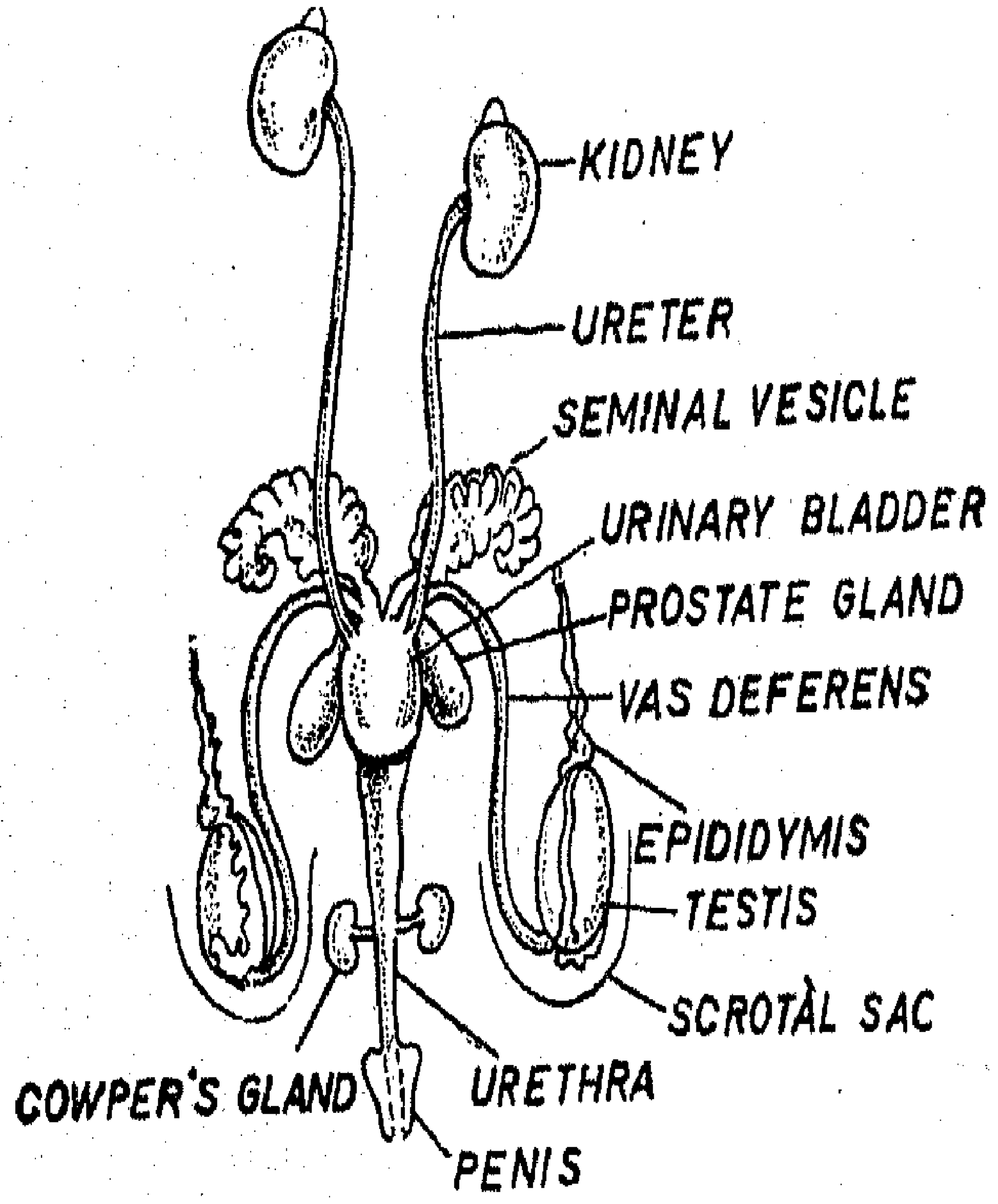


Fig. 147. *Rat : Male Urino-genital System*

A pair of perineal glands (*odoriporous glands*), which emit a particular odour, are present one on either side near the base of the penis.

(The male reproductive system of the rabbit differs from that of the rat in that in the rabbit, there is an absence of the seminal vesicles and the presence of a median sac called the uterus masculinus, into which open the vasa deferentia. The uterus masculinus opens, in turn, into the urethra.)

In the female rat, the reproductive system consists of two ovaries and two fallopian tubes (oviducts). (Fig. 148). These fallopian tubes are convoluted. Each one is continued into a thick-walled uterus. The two uteri of the two sides open into a median vagina, which opens to the outside by a female genital opening.

Rats and rabbits, unlike human beings, liberate more than one ovum at a time (multiovulate). These ova independently get fertilised and develop inside the uteri to produce a large

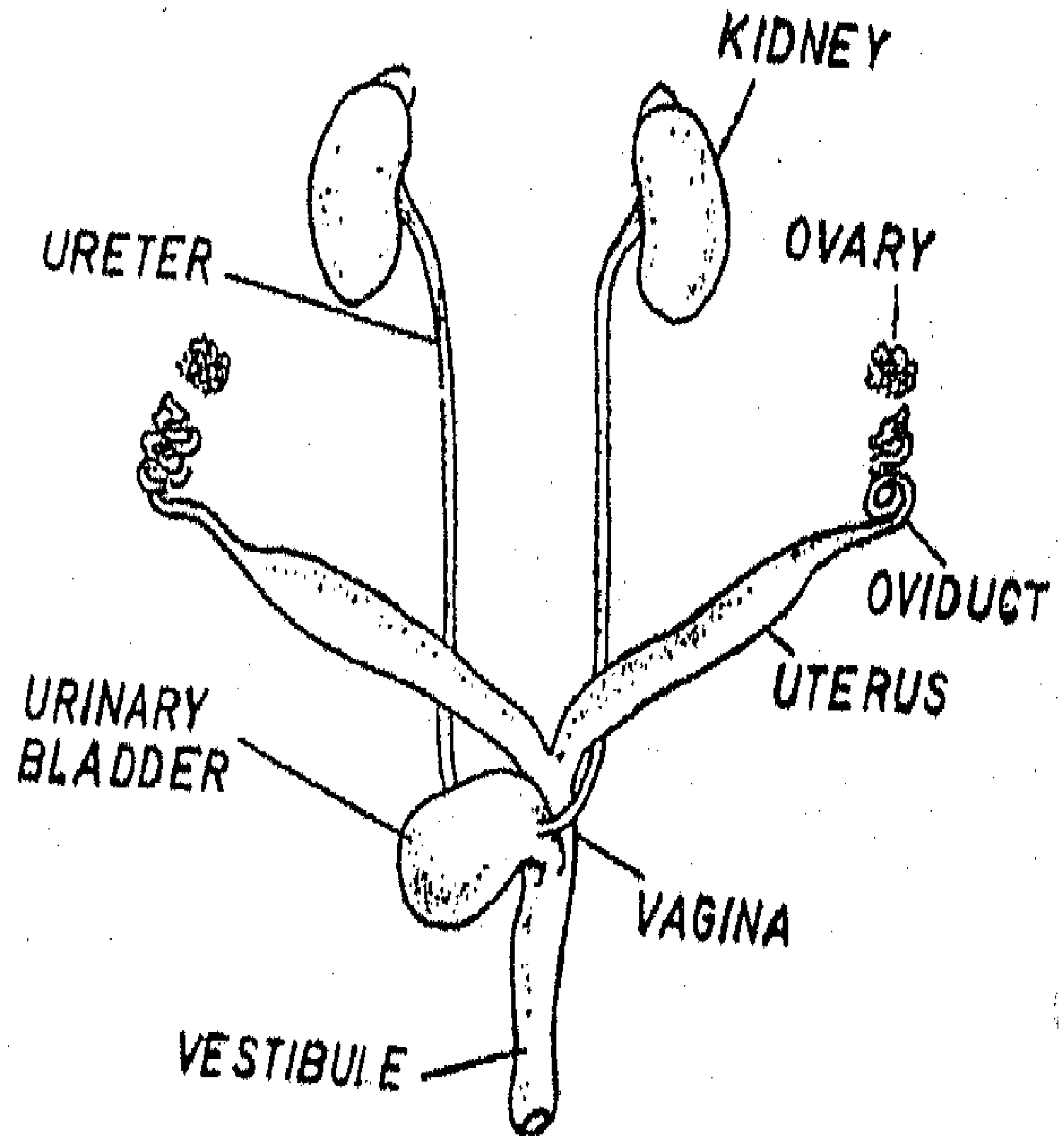


Fig. 148. *Rat : Female Urino-genital System*

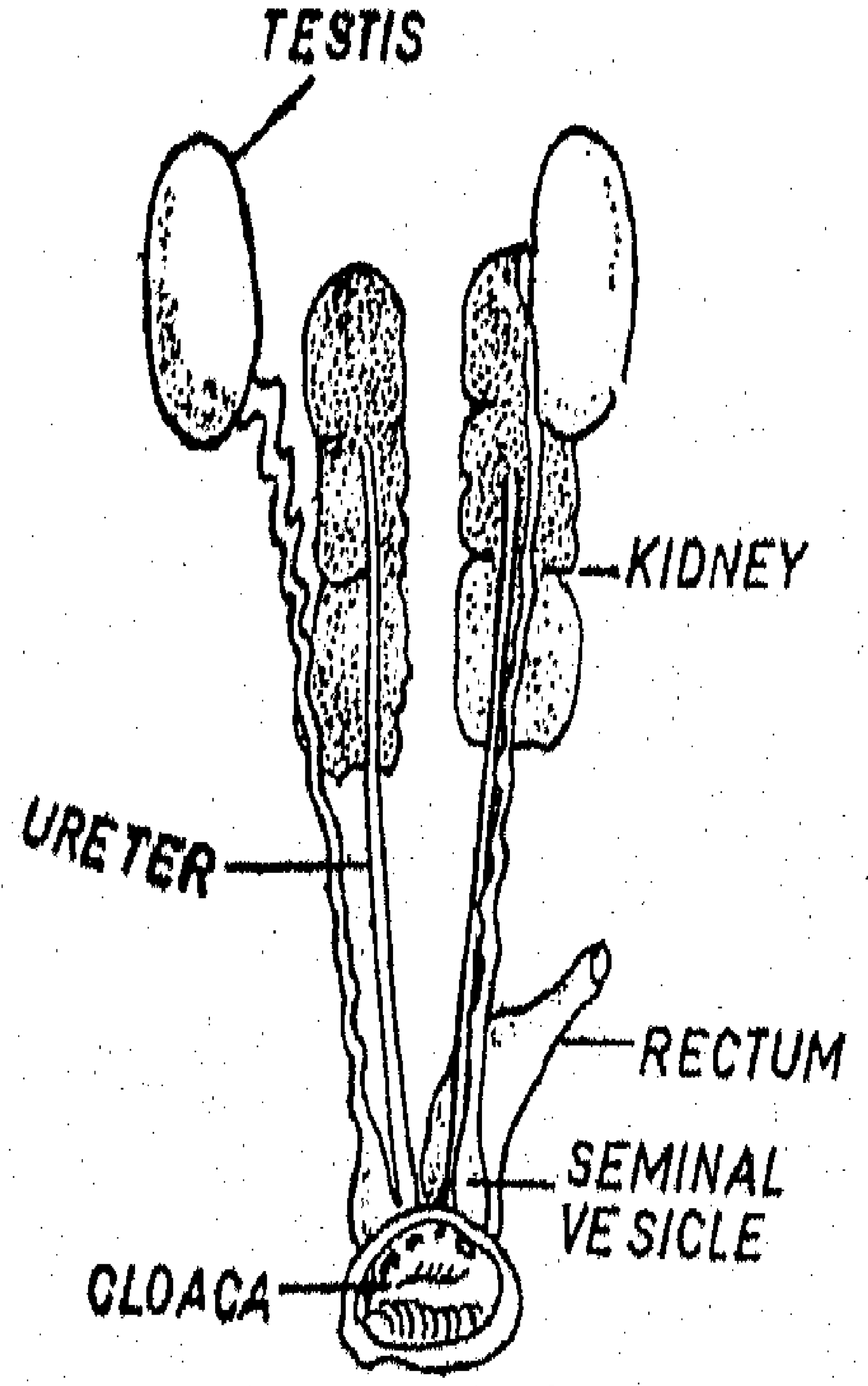


Fig. 149. *Pigeon : Male Urino-genital System*

number of young ones (about 4-8). These young ones together constitute a litter.

Reproductive System of Bird (Pigeon)

Male Reproductive System. In male birds, the testis are oval and are attached to the anterior face of each kidney. (Fig. 149). The vas deferens, which is given out from its posterior side, runs almost parallel to the ureter and opens posteriorly into the cloaca. The anterior most region of the vas deferens near the testis is often termed as epididymis, and the slightly swollen region near the cloaca is referred to as the seminal vesicle. Here, the seminal vesicles act as temporary reservoirs of spermatozoa.

There are no other accessory glands in the birds. There is no copulatory organ. During copulation, the sperms are passed into the cloaca of the female body by the direct apposition of the cloaca of the male and the female birds.

Fertilisation is internal.

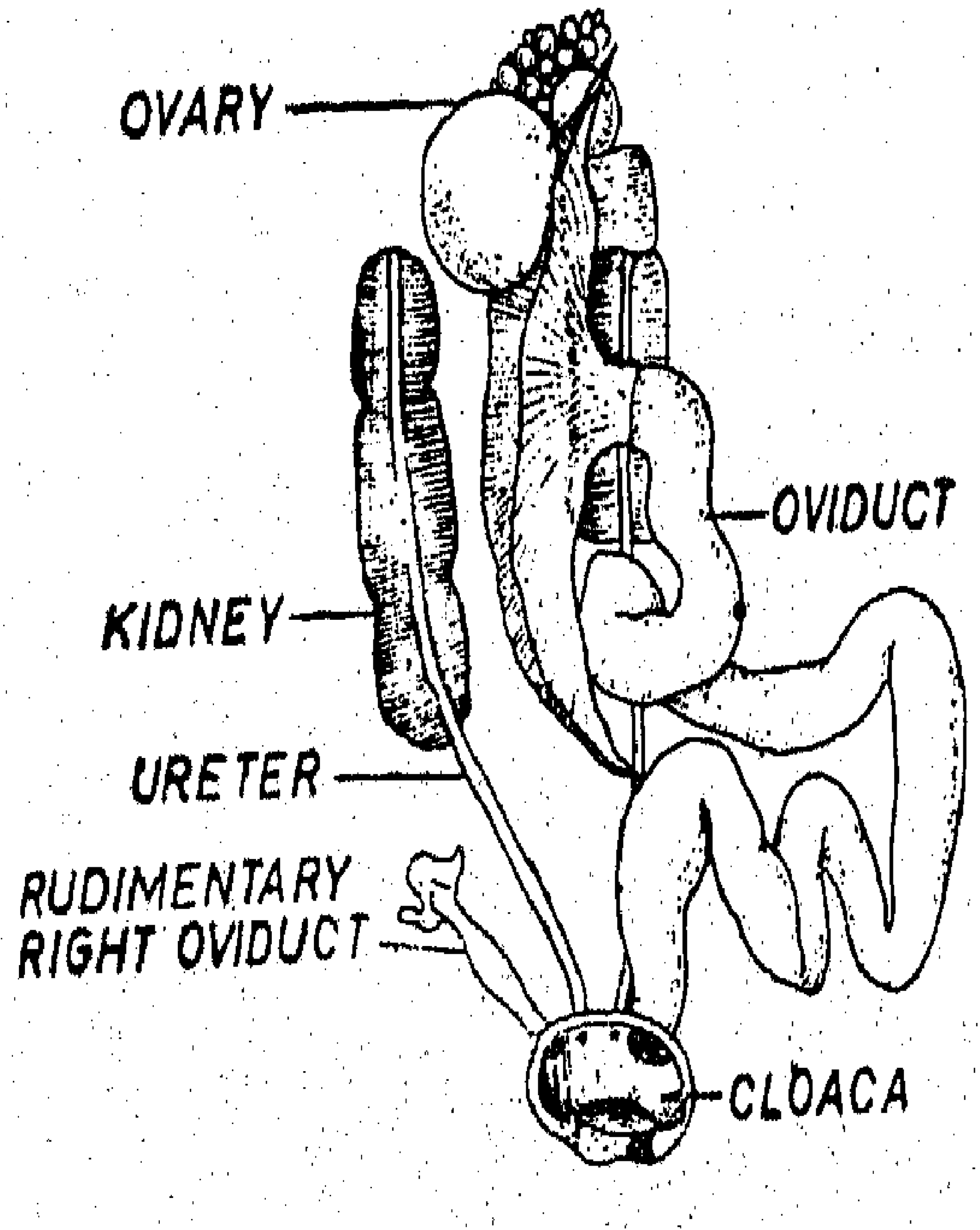


Fig. 150. *Pigeon : Female Urino-genital System*

Female Reproductive Systems. There is only one ovary and one oviduct on the left side. (Fig. 150). The right ovary is completely absent and the right oviduct is either completely absent or formed as a rudiment. The absence of one ovary and an oviduct reduce the weight of the body, which is made lighter. Had the other oviduct been present, there would be a risk of collision between two fragile eggs coming down simultaneously from the two oviducts in a narrow cloaca.

The left ovary is well-developed with a large number of ova at different stages of development. The left-oviduct, during the breeding season, is much dialated and richly supplied with blood vessels and is very much convoluted. At its anterior end, it has a funnel-shaped opening, the oviducal funnel. Posteriorly, it opens into the cloaca.

After ovulation, the mature ovum is taken into the oviducal funnel. In the neck region, it gets fertilised. As the ovum (fertilised or unfertilised) passes downwards through the oviduct, it is covered by layers of albumen, then by two thin shell membranes, and ultimately by a porous shell of $CaCO_3$. (Fig. 151) All these layers are the secretions of the glandular linings of the oviduct at different places. After the shell is formed, the egg is passed into the cloaca, from where it is laid to the outside. The egg is incubated by the warmth of the female bird, which sits over it till it is hatched. The development of the fertilised ovum takes place inside the egg, and a small young one hatches out.

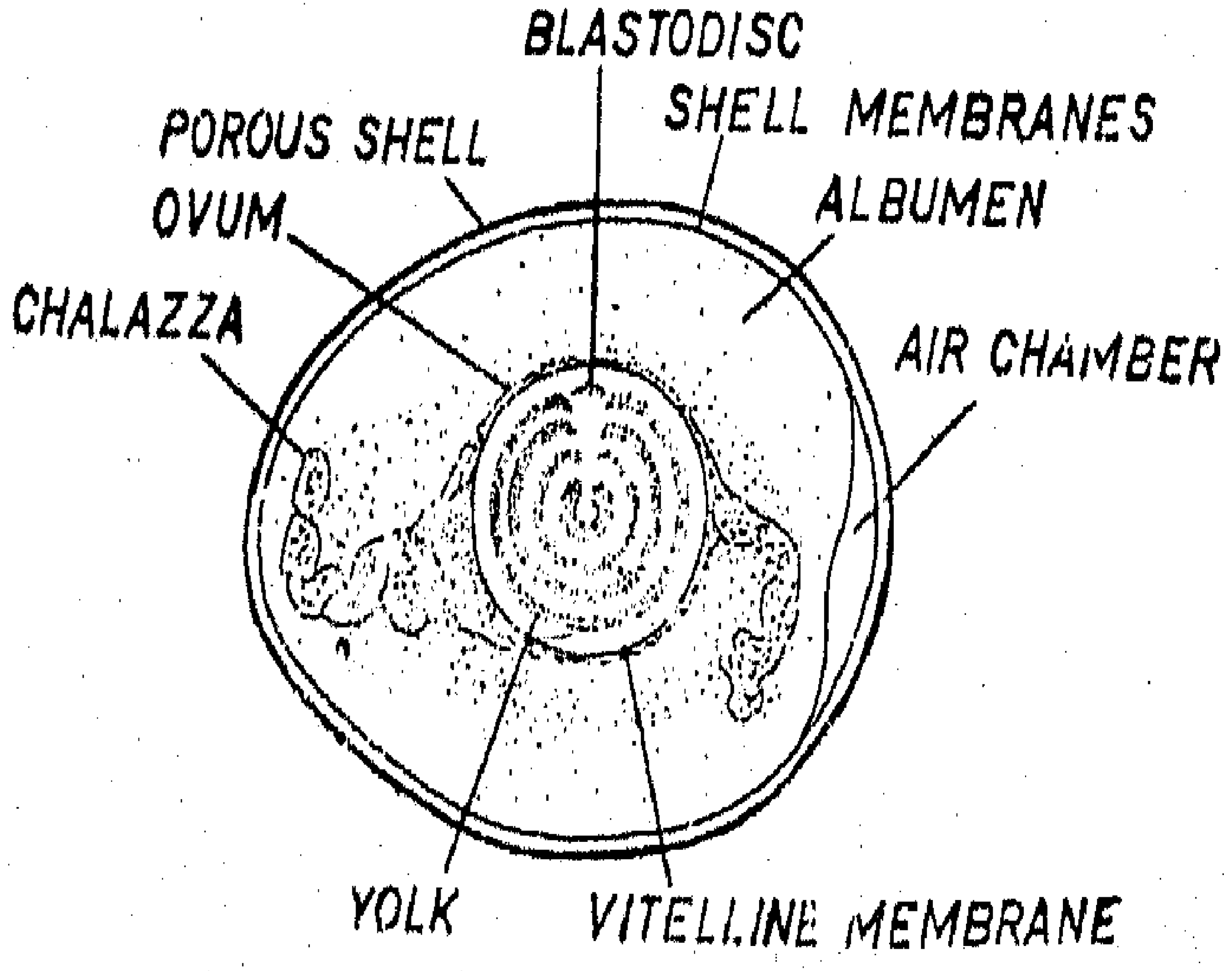


Fig. 151. *Egg of a Bird*

Since they lay eggs, birds are oviparous.

Reproductive System of Frog

Male Reproductive System. The male reproductive organs are the two testes, which are small, elongated, yellowish bodies attached one each to the anterior end of the kidney. (Fig. 152 A). About 6 to 8 fine vasa efferentia pass from each testis into the kidney Through these vasa efferentia, the spermatic fluid is passed into the kidney for its further removal to the outside. The ureter running down from the outer margin of each kidney in the male serves also as the passage for the genital product, and hence is known as the urino-genital duct. The two urino-genital ducts open dorsally into the cloaca. There is no copulatory organ.

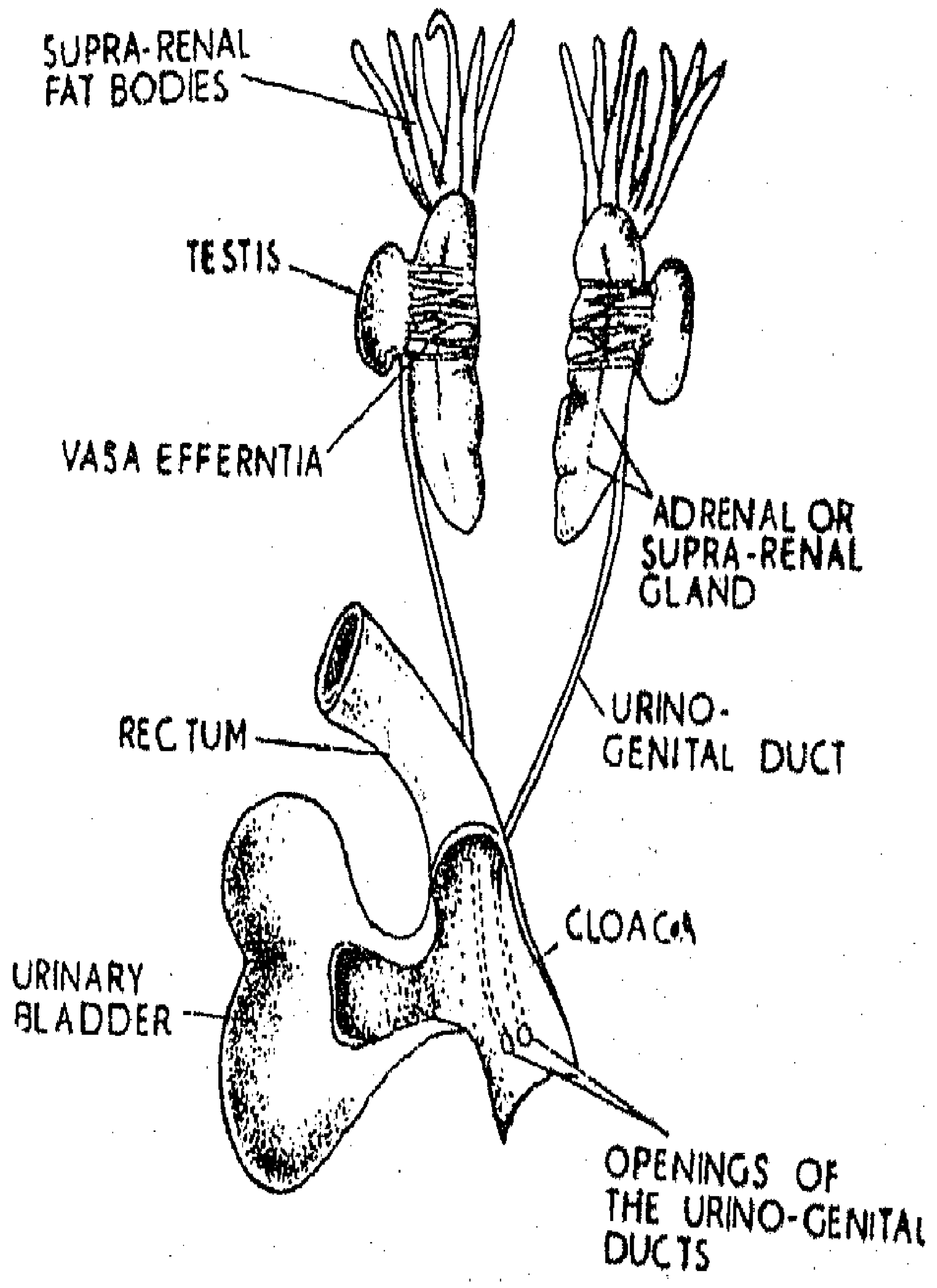


Fig. 152-A *Frog: Urino-genital System*

Female Reproductive System. The female reproductive organs are the two ovaries attached to the anterior ends of the kidneys. (Fig. 152 B) Each ovary is almost a hollow sac-like organ lined with germinal epithelium. The ovary is produced in the form a large number of irregular lobes. A large number of ova is produced in each ovary. Each ovum is enclosed in an ovarian follicle.

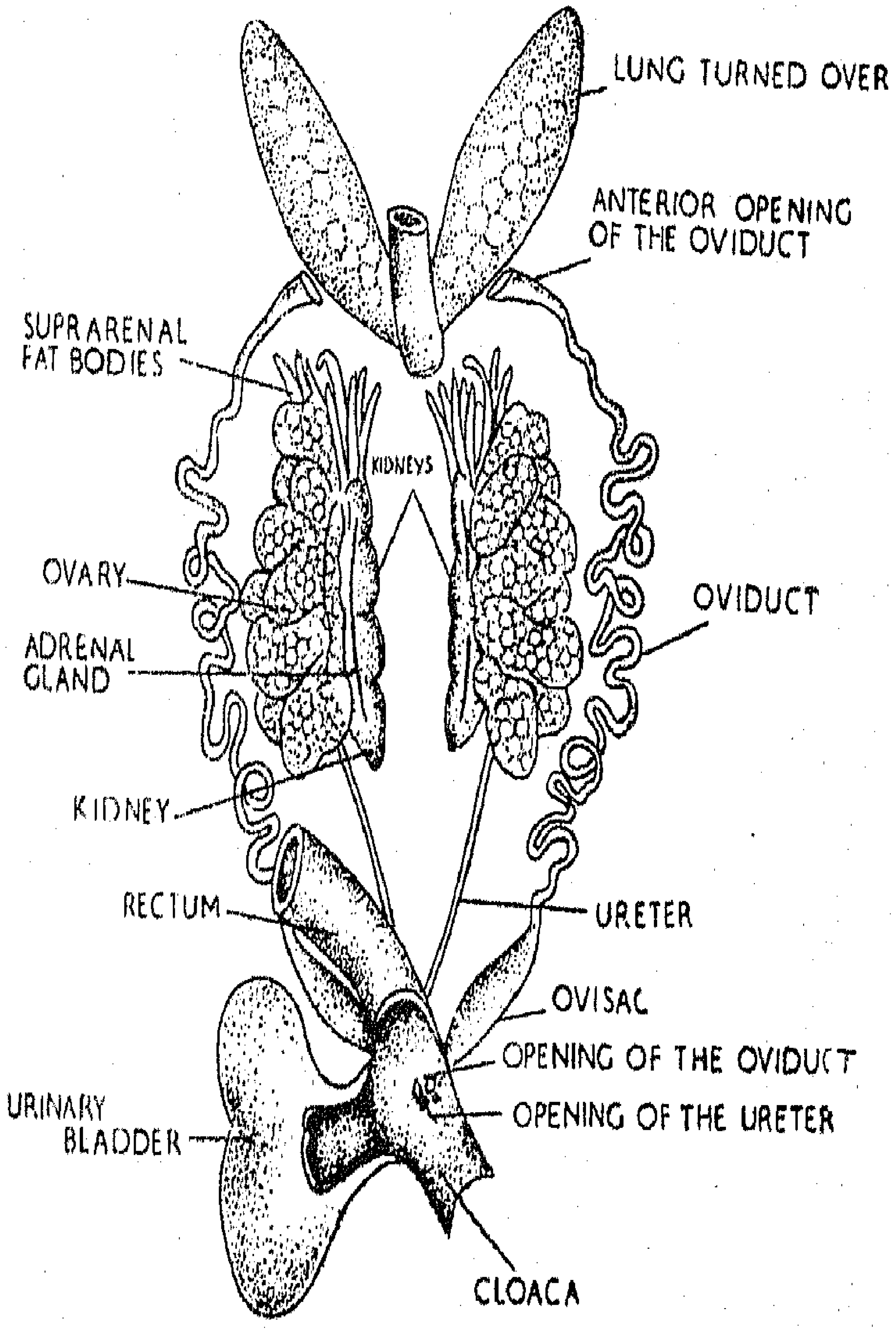


Fig. 152-B. *Frog: Urino-genital System*

The oviducts are two in number. They are long, coiled tubes. Their anterior ends bear funnel-shaped structures called oviducal funnels found near the base of the lungs and away from the ovary. The posterior end of each oviduct is enlarged to form an ovisac. Ovisacs, unlike the uterus, serve only to store the eggs but cannot nourish them. The wall of the ovisac produces some gelatinous secretion, which binds the ova together.

During copulation, the male sits over the female, and due to the pressure exerted over the abdomen of the female by the clasping of the male, the eggs are thrown out of the cloaca as a sticky gelatinous mass. This egg mass is called the spawn.

Soon after the spawn is given out, the male sheds the spermatic fluid over it and thus the sperms fertilise the ova. Fertilisation, therefore, is external. They are oviparous since they lay eggs.

Reproduction in Invertebrates

Reproduction in Hydra. It takes place by both sexual and asexual methods. In Hydra, asexual reproduction takes place by budding and also binary fission.

Budding. A bud appears in the form of a small spherical outgrowth on the surface, usually towards the basal end of the animal. (Fig. 153). It is formed by the rapid division of the ectodermal and endodermal cells of the body wall. This bud elongates and becomes cylindrical. The coelenteron of the parent extends into it. The mouth appears terminally as a small opening, leading into the coelenteron. It gets surrounded by a circlet of tentacles. A constriction appears at its base and goes on deepening till the bud is cut off from the parent body. The young hydra thus becomes an independent individual.

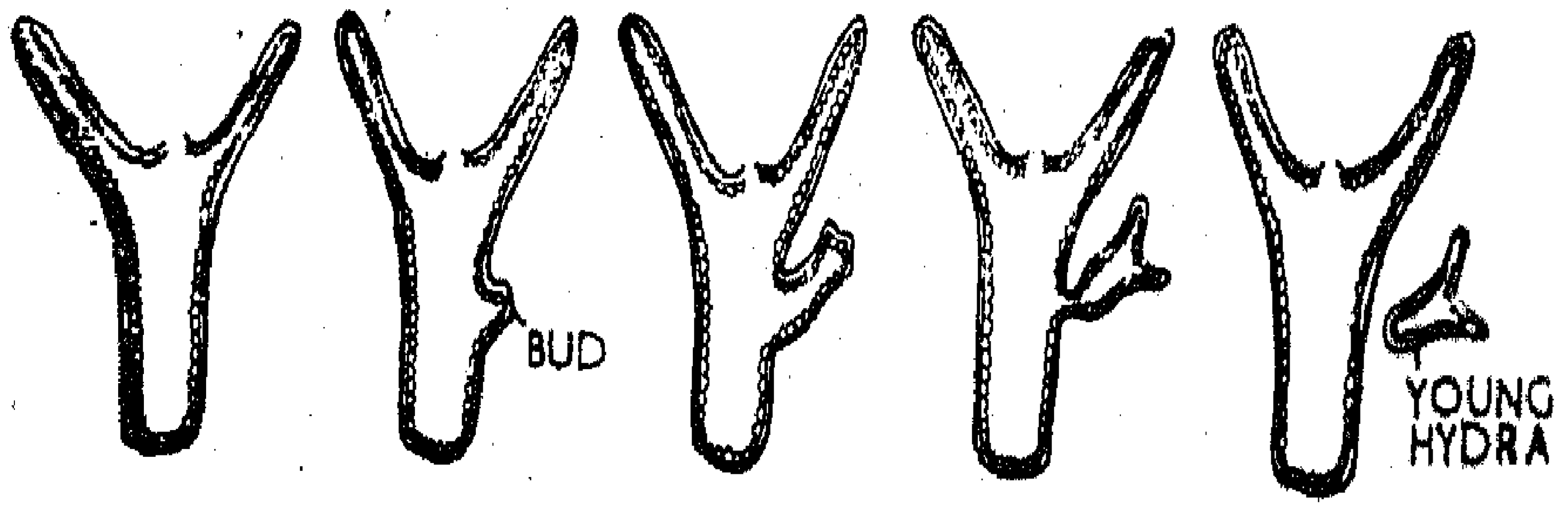


Fig. 153. *Hydra: Budding*

Binary Fission. The hydra occasionally reproduces by splitting into two, sometimes longitudinally and at other times transversely. Each half thus formed regenerates the other half.

Sexual Reproduction. Most of the species of Hydra are bisexual *i.e.*, hermaphrodite. They possess both the male and the female reproductive organs in the same individual. Some of them are, however, unisexual.

The testis develop as conical elevations towards the oral end, and the ovaries arise as rounded projections towards the basal region. (Fig. 154). These gonads are fromed by the repeated division of the ectodermal cells. The testis produces a large number of spermatozoa, which are liberated into the surrounding water. The ovary contains only one ovum, which enlarges due to the accumulation of the food matter, the yolk, useful for the developing embryo.

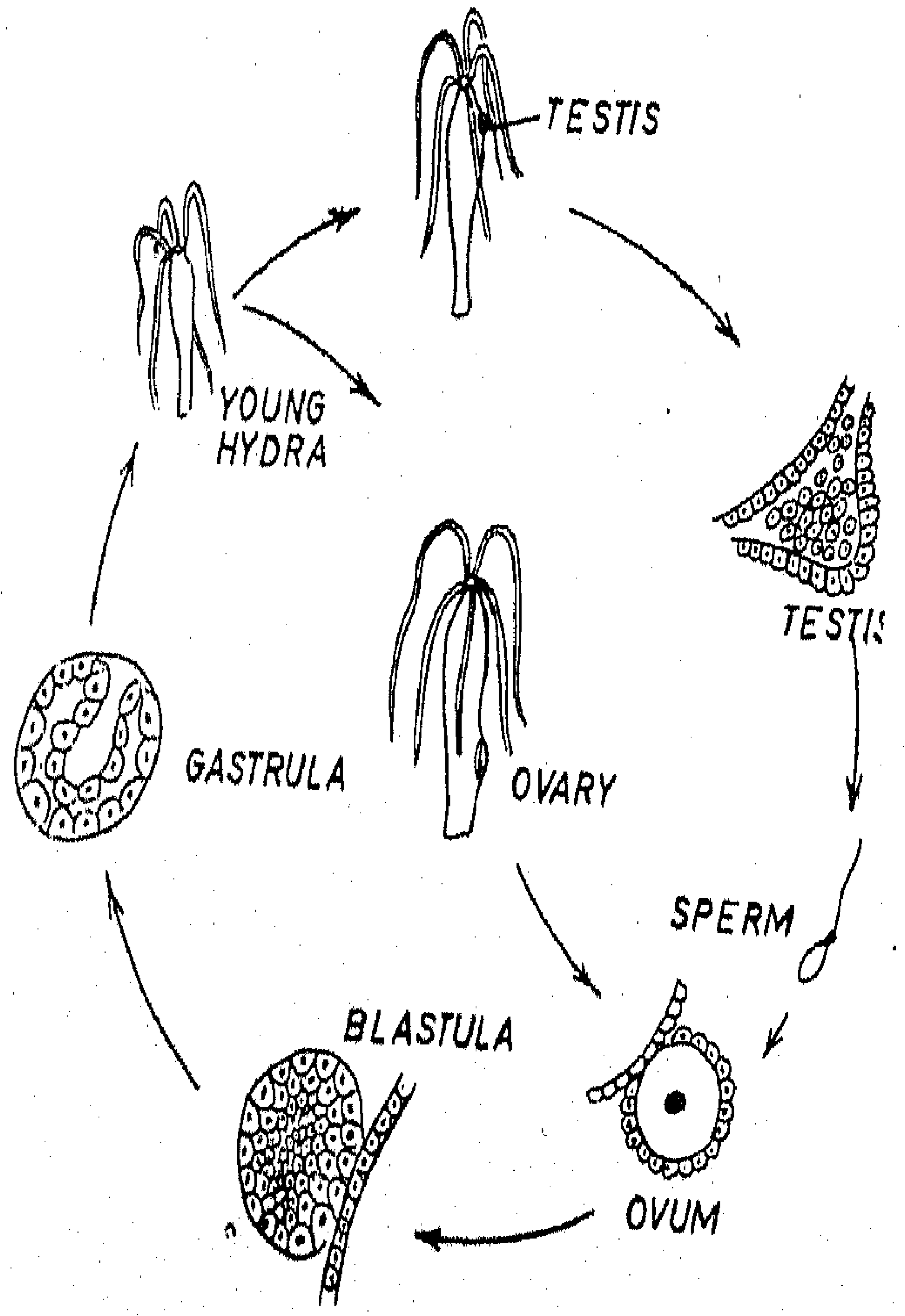


Fig. 154. *Hydra: Sexual Reproduction*

Though the animal is hermaphrodite, cross-fertilisation takes place. Self-fertilisation is avoided by the testis maturing earlier than the ovary. When the ovum is mature, it protrudes out of the ovary, and in that position it gets fertilised to form the zygote. The zygote develops into a new hydra, still attached to the parent. It detaches later on to lead an independent life.

Reproduction in Amoeba. The amoeba reproduces only asexually, there being no sexual reproduction. The asexual reproduction is by binary fission and also by multiple fission.

Binary Fission. The nucleus first starts dividing into two nuclei, which then separate, (Fig. 155). Simultaneouly, a constriction appears in the cytoplasm, which goes on deepening. Finally, the nuclear division and the cytoplasmic division are completed, producing two individuals, each one growing into a new amoeba. During this process, the contractile vacuole suspends its activities.

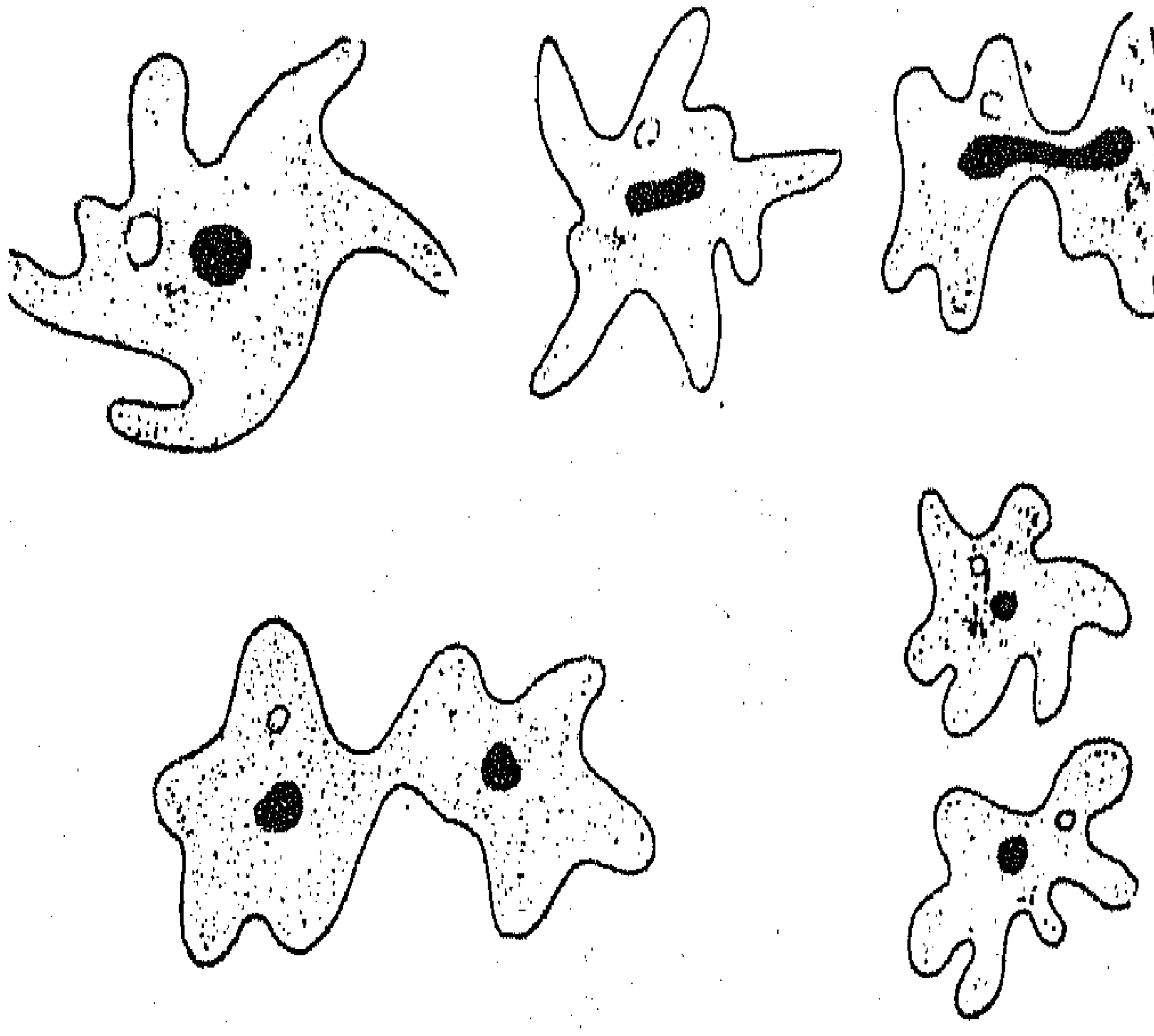


Fig. 155. *Amoeba: Binary Fission*

Multiple Fission. However, under unfavourable conditions, when the pond, in which the amoeba lives, dries up, all the pseudopodia are withdrawn and the animal gets rounded. It secretes a double-layered wall, the cyst. (Fig. 156). In this encysted condition, it remains dormant or quiescent and tides over the difficult period. Within the cyst, the nucleus divides repeatedly, and each daughter nucleus gets surrounded by a bit of cytoplasm, which forms a spore. When favourable conditions return, the cyst bursts and the spores are set free, which then develop into numerous small amoebae known as amoebulae. These later on develop into adult individuals. This process of reproduction is multiple fission or sporulation.

B

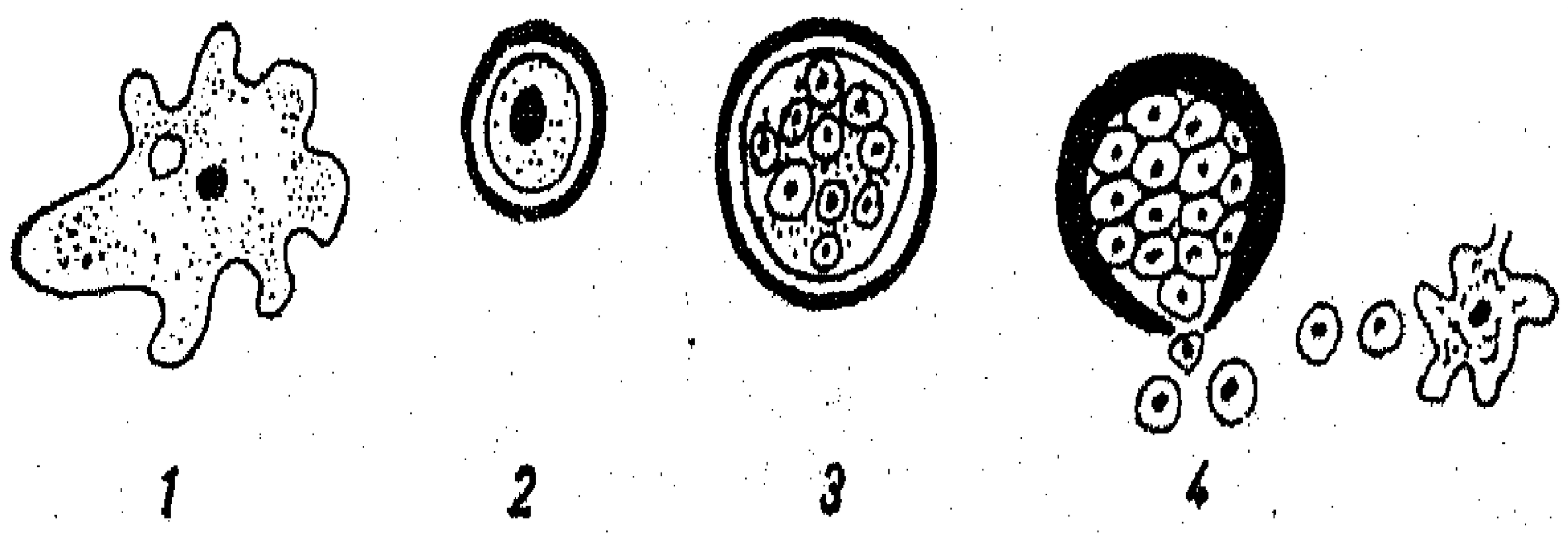


Fig. 156. *Amoeba—Multiple Fission*

SUMMARY

1. Reproduction means the production of individuals of its own kind.
2. The two methods of reproduction are (a) Asexual and (b) Sexual.
3. The important male genital organs are testis which in the case of man lie in the Scrotal sacs.
4. The penis is the copulatory organ whose main function is to deposit seminal fluid into the vagina of the female.
5. The Sperm or Spermatozoa fertilizes the ovum.
6. The ovaries are the essential structures of the female genital organs.
7. One ovum is liberated alternately from each ovary once in every 28 days.
8. The unfertilized egg is discharged during menstruation.
9. In Rabbit there is the absence of seminal vesicles.
10. In the female rat there are two uteri which open into the median vagina.
11. Rat and rabbit liberate more than one ovum at a time.
12. In bird there is no copulatory organ.
13. In male bird the ureters, the seminal vesicles and the large intestine open into cloaca.
14. In the female bird, there is only one ovary and an oviduct, the right ovary being absent and the oviduct rudimentary.

15. Birds are oviparous as compared to mammals which are viviparous.

16. In male frog the Sperms and waste products are carried by urino-gential duct.

17. The eggs of frog are fertilized externally by male frog.

18. Reproduction in hydra is asexual and sexual.

19. Asexual reproduction is by budding and binary fission.,

20. Amoeba produces asexually by binary or multiple fission, there being no sexual reproduction.

BIOLOGICAL WORDS

Epididymis
Seminiferous tubules
Fallopian tube
Ovulation
Cloaca
Seminal Vesicle
Budding
Binary fission

QUESTIONS

1. What is Sexual reproduction? Describe the male reproductive system of any vertebrate animal studied by you.
2. Describe the female reproductive system of any two of the following :
   (i) Pigeon (ii) Frog (iii) Human being
3. Write short notes on:—
   (i) Budding in hydra (ii) Reproduction in Amoeba (iii) Sperm, (iv) Ovum (v) Placenta (vi) Egg of a bird.

Development 13

The zygote is the result of fertilisation, which gives the necessary impetus to the future development of the egg, It undergoes a series of orderly changes before it attains the adult stage. This process of developmental changes, which the zygote undergoes, is termed as *Embryology*.

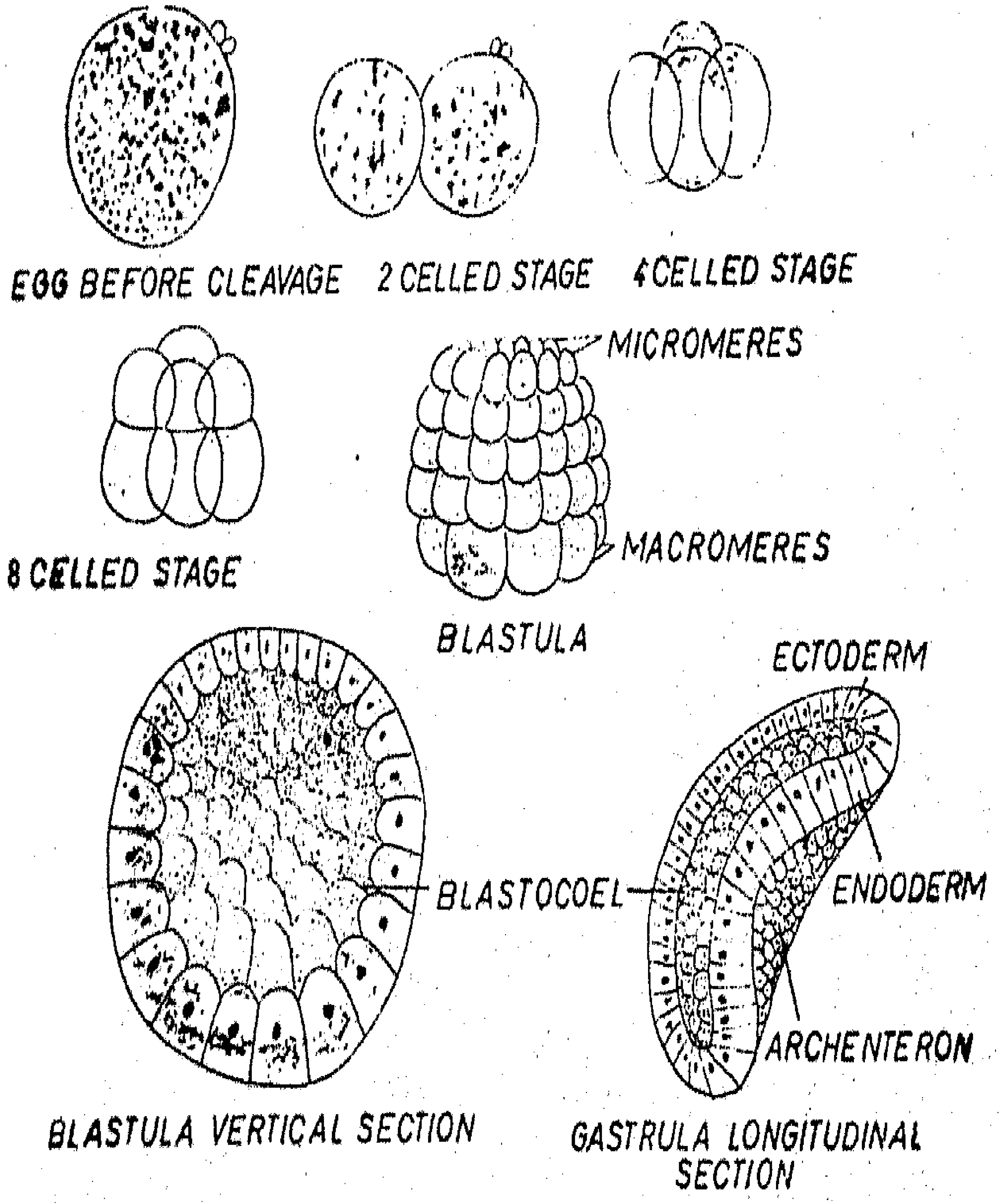


Fig. 157. *Embryological Stages in Development*

(1) Segmentation or Cleavage; (2) Blastula formation; (3) Gastrulation; and (4) Organogeny.

(1) **Segmentation or Cleavage.** During cleavage, the zygote divides in an orderly manner, producing a solid mass of cells called the *morula*. The cells of the morula thus formed are called *blastomeres*. The smaller blastomeres are called *micromeres* and the larger ones are known as *macromeres*. This process of division is called cleavage or segmentation.

(2) **Blastula formation.** After a period of segmentation, a small cavity appears inside the morula which becomes a hollow sphere of blastomeres. The embryo now is called the *blastula*. The fluid-filled cavity inside is formed as the result of segmentation and is called *segmentation cavity* or *blastocoele*.

(3) **Gastrulation.** In this process of gastrula formation, the cells of the blastula arrange themselves into two definite embryonic layers. This is usually achieved by the intucking or invagination (*emboly*) of the lower cells of the blastula into the upper layer of cells; or may be formed due to the over-growth (*epiboly*) of the upper micromere cells over the lower micromeres; or it may be the result of both the processes. During this process, the blastocoele is slowly obliterated, and a new cavity is formed which is called the *gastrocoele* or *archenteron* (which is the future alimentary canal), and its opening to the outside is known as the *blastopore*. (In the region of *blastopore*, the future anus would normally appear.) In this two-layered gastrula, the outer layer is called the *ectoderm* and the inner, the *endoderm*.

At a later stage, the third layer, called the *mesoderm*, is formed between the ectoderm and the endoderm. This layer is formed only in *triploblastic* animals. Since the different organs of the developing individual are formed from these layers, they are described as germ-layers or germinal layers.

(4) **Organogeny.** It is a process of formation of different organs from the germinal layers by a process of differentiation.

The grouping of these various organs into definite systems gives rise to a well-formed young one, similar to the parent in all respects.

In fishes, reptiles, birds and mammals, the young one that is born is similar to its parents in all respects. This development is called *direct* development.

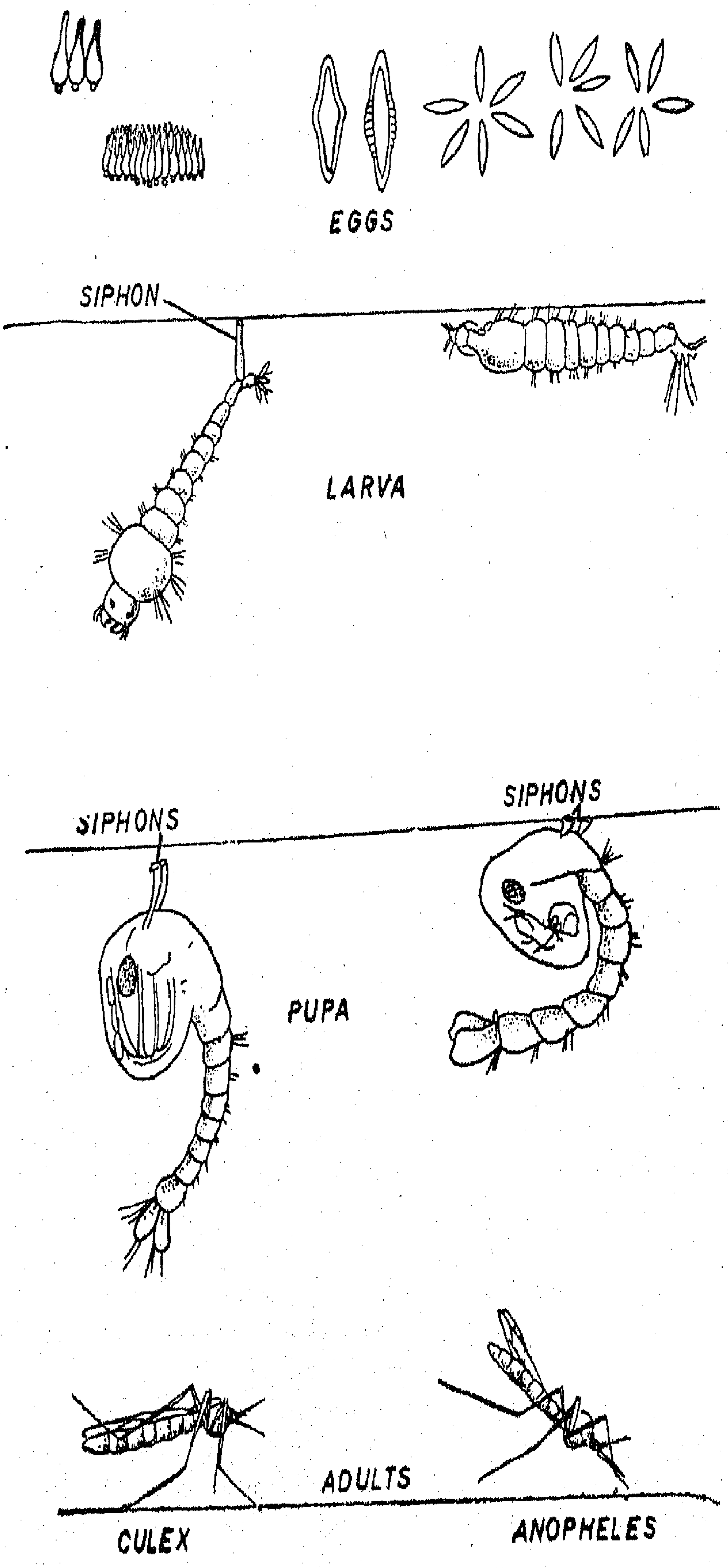


Fig 158. *Mosquito-Life History*

In some animals, like frogs, and insects like the mosquito, the butter-fly, the house-fly, the silkworm, ete., the young one, or the embryo that hatches out from the egg, is not fully formed, and is very much dissimilar from the parent, both in form and habits. It is called the *larva*. It has to undergo a series of structural changes before it attains the adult stage. This process of changes, through which the larva has to go before it is transformed into the adult, is referred to as *Metamorphosis*. Thus the development of these animals is called *indirect*.

Life History of Mosquito

Mosquitoes are abundant in marshy places and near stagnant waters. Two common types of masquitoes are the *Anopheles* and the *Culex*. The Anopheles are the carriers of malariral parasites, which they transmit from man to man. The Culex transmits germs which cause the disease known as *Elephantiasis* in man. Thus mosquitoes are of considerable importance.

Eggs. The female lays the on the surface of the stagnant water. (Fig. 158.). The Culex lays about 200 to 300 eggs glued together to form an egg-raft, which floats in the water. Each egg is cigar-shaped. The Anopheles lay the eggs singly. These eggs are boat-shaped, and are provided with a frill of small air spaces and a float on either side.

Larva. The egg hatches in about 2 or 3 days into a small wriggling young worm called the *larva*. The body consists of a head, thorax and abdomen. The head is large and rounded, bearing a pair of compound eyes, a pair of simple eyes (or *ocelli*), a pair of feelers or antennae; it is provided with a pair of tufts of hair called the feeding brushes. The movement of these brushes creates a water current which drives small organisms and other food particles into the mouth. The mouth parts are adapted for biting and chewing. The thorax is unsegmented, and bears 3 pairs of bristles at the sides. The obdomen consists of 9 segments, each bearing a tuft of bristles. The 9th segment bears four small leaf-like plates, which contain the trachea, and are called *tracheal gills*, which act as accessory respiratory organs. In the Culex, the 8th segment bears a small tubular structure called *siphon*. The two tracheae open at the tip of this siphon, which is used for respiration. In order to keep the opening of the siphon above the surface of the water to breathe in air, the Culex larva is always found to hang head downwards, obliquely to the surface of the water.

This siphon is absent in Anopheles larva, in whom the tracheae open dorsally flush with the surface of the 8th segment. Thus the larva lies in a horizontal position just beneath the surface of the water during breathing. The larval period is of about 8 to 10 days duration.

Pupa. The larva casts its skin or moults 3 or 4 times before it passes into the next stage known as the *Pupa*. It has a large anterior portion, the *cephalothorax*, which is formed by the fusion of the head and the thorax, and a bent posterior abdomen of 9 segments, which ends in a pair of flat plates forming the tail fin. The head and thorax are covered by a transparent membrane, the *puparium*. The thoracic region bears a pair of air trumpets or siphons, which are connected internally with the tracheae. These are used in respiration. The pupa cannot feed, but unlike the pupa of other insects, it is very active and has the power of locomotion. If disturbed, it darts downward by the movements of its abdomen, and it rises again to the surface after some time. In Anopheles, the abdomen of the pupa is more bent and the siphons are short and wide.

Inside the puparium, the pupa undergoes remarkable changes towards the formation of the adult structures. At the end of 2 or 3 days, the adult or *imago* emerges out, breaking open the puparium; and then it flies off.

Imago. The body of the adult mosquito is composed of three regions, the head, the thorax and the abdomen.

The head bears a pair of large compound eyes, a pair of antennae and a proboscis with piercing and sucking mouth parts.

The thorax is of 3 segments, each segment bearing a pair of jointed legs. There is only one pair of wings.

The abdome is segmented and is made up of 8 segments.

The male mosquito normally lives on plant juices, while the female feeds on the blood of vertebrates.

The adults of the Culex and Anopheles can be easily distinguished, not only from their structural differences but also from their sitting posture. The Culex sits almost paralled to the surface on which it rests, while the Anopheles makes an angle with the resting surface.

Life History of Frog

The life history of frog involves embryonic and post-embryonic phases of development. There is a larval stage known as the tadpole, which undergoes metamorphosis before it attains adult characteristics.

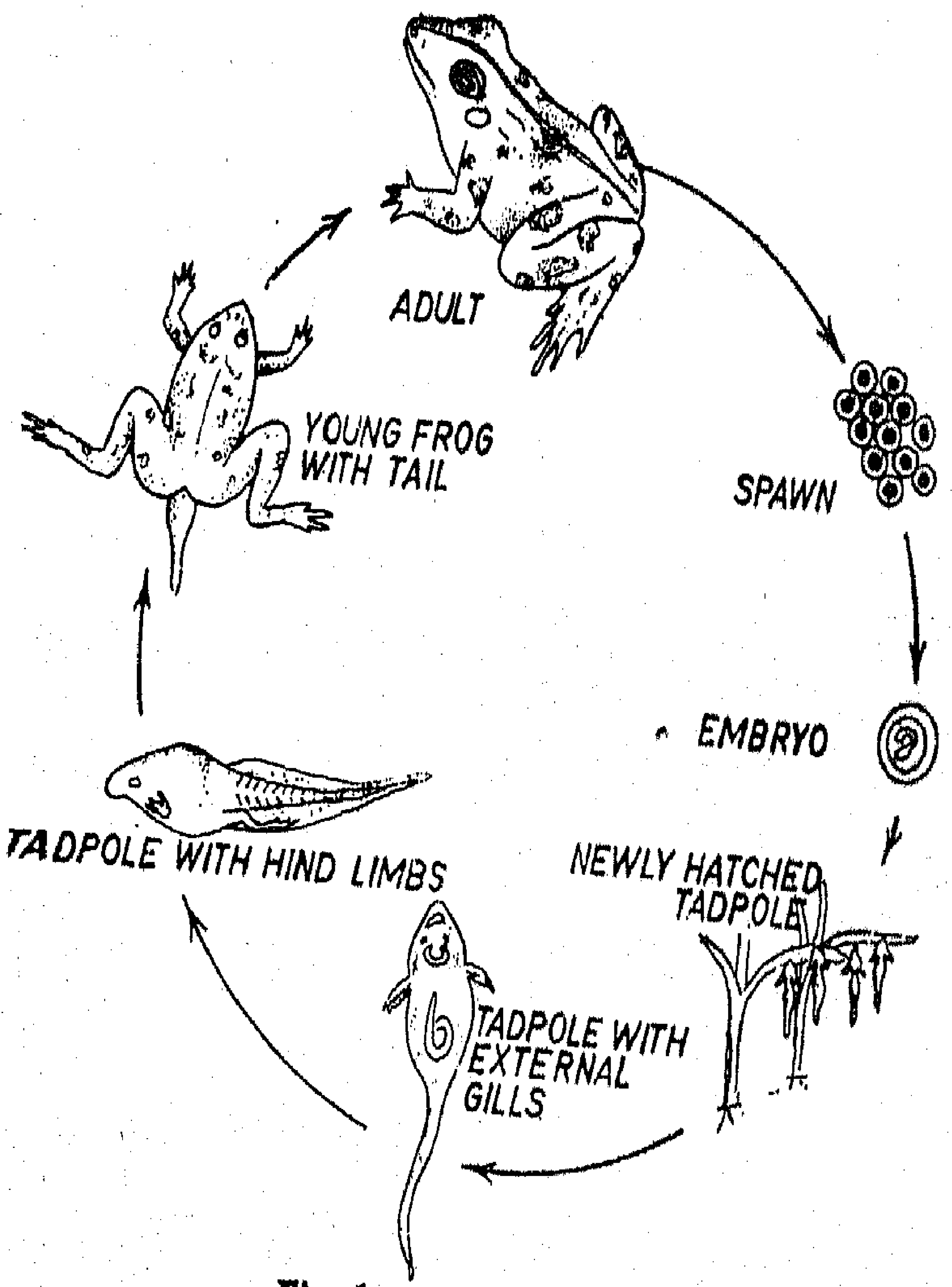


Fig. 159. *Frog: Life History*

Eggs. They are laid in large number in water. The mass of eggs is called the spawn. (Fig. 159). The jelly covering the eggs swells up after imbibing the water, thus spacing the eggs for proper development and growth. The eggs are fertilised by the sperms shed over them by the male during copulation.

Embryonic development. Eggs after fertilisation undergo cleavage, as a result of which a blastula is formed. The blastula then develops into a double-layered gastrula, which soon grow a third germinal layer. The embryo elongates and, within a fortnight from fertilisation, it hatches out into a larva known as the *tadpole*.

Post-Embryonic Development

(1) **Larva with external gills.** It is almost fish-like in appearance and possesses 3 pairs of external gills at the sides of the body. It has a small tail. It is without any eyes and mouth. It attaches itself to water weeds by means of a ventral horseshoe-shaped sucker. It lives on the yolk matter that persists in the body. This is the *external gill stage*. Soon the mouth appears as a slit; which is provided with horny jaws. Now the tadpole begins feeding on vegetable matter. The intestine elongates, and lies spirally coiled inside the abdomen. The eyes make their appearance, and the sucker disappears. The tail elongates, and develops fin-like folds. The tadpole swims actively with the movements of the tail.

(2) **Larva with internal gills.** The external gills soon disappear, and the tadpole develops 4 pairs of gill clefts, around which 4 pairs of internal gills arise. A fold of skin, the *operculum*, grows to cover the gills of both the sides, leaving only a small aperture called the *spiracle* on the left side. Now the tadpole breathes like a fish, where the water enters the mouth, flows over the gills and passes out through the spiracle.

(3) **Larva with limbs.** The limbs make their appearance as small buds, and later on grow to their normal size. The fore-limbs develop first; but since they are enclosed by the opercular fold, the hind limbs make their appearance first and the fore-limbs are seen later.

The lungs appear as rudiments from the ventral surface of oesophagus and the tadpole, for some time is truly amphibious. It can breathe by gills in water and also can breathe air by lungs when it occasionally comes to the surface of the water.

(4) **Metamorphosis to adult stage**. The tadpole now undergoes rapid and drastic changes towards transformation into an adult. The horny jaws are replaced by bony jaws and teeth. The mouth widens, and the eyes grow. The internal gills and spiracle disappear; lungs enlarge and are now used to breathe oxygen from air. The two-chambered heart becomes three-chambered. Skeletal elements become ossified into bony structures. The intestine becomes shorter, and the animal leaves its vegetarian diet and becomes carnivorous. The tail becomes shorter and ultimately disappears, and the limbs increase in size.

The result of all these changes is the formation of a tiny little frog, still with a rudiment of the tail. It hops out of the water and comes on land. The tail disappears, and the metamorphosis is complete. Thus, from an aquatic, gill-breathing tadpole, through metamorphosis, a terrestrial lung-breathing frog is formed.

Frogs also breathe by skin; and occasionally they plunge into water so as to keep the surface of the skin moist. If the skin is allowed to dry, the animal would die of desiccation. That is why, even in its adult condition, the frog is amphibious in habit.

SUMMARY

1. Process of the developmental changes which the zygote undergoes is termed embryology.
2. In mosquito and frog, metamorphosis is present.
3. In mosquito the stages in the life history are:
   (1) Eggs (2) Larva (3) Pupa and (4) Imago.
4. The adults of Culex and Anopheles can be distinguished from their sitting posture.
5. The mass of eggs of frog is called the Spawn.
6. The various stages in the development of frog are:
   (a) Larva with external gills (b) Larva with internal gills
   (c) Larva with limbs and (d) Adult stage.

BIOLOGICAL WORDS

Blastula
Cleavage
Gastrulation
Larva
Pupa
Imago
Tadpole
Metamorphosis

QUESTIONS

1. What is metamorphosis? Describe it with reference to Mosquito or Frog.
2. What are the differences between Eggs. Larvae. Pupae of Anopheles and Culex.
3. Write short notes on:—
   (i) Tadpole of Frog (ii) Larvae of Mosquito

Nervous System

14

All functions in an organism are accurately controlled and adjusted. They are correlated with the function of the organs and are integrated according to the needs of the body. The co-ordination and control of the various activities of life are not only due to the hormonal complex in the body but also to a specialised system, the Nervous System. The nervous system, with its sense or receptor organs like the eye, ear, etc., receives stimuli (singular, stimulus) from environment, external and internal, and accordingly brings about the response to these stimuli.

Living organisms are sensitive to changing environment, both external and internal, and accordingly they respond or react to these different stimuli. The various stimuli received by the sense organs are conducted to the central nervous system, which brings about the necessary responses.

The fundamental characteristic of the protoplasm is its irritability and conductivity. Thus, in acellular animals like the amoeba, where there is no differentiation into tissues and systems, the reception of the stimulus and the conduction of the impulse and the response are carried out by the undifferentiated mass of protoplasm. However, in multicellular animals, these activities are confined to certain groups of cells, differentiated and specialised in the form of organs and systems. To receive stimuli, there are special receptors or sense organs in the body, and there are specialised effectors like muscles and secretory cells, which respond to these stimuli.

In sponges, there are no specialised organs for the reception and conduction of impulses ; but they are passed on from one cell to another.

For the first time in the animal kingdom, nerve cells make their appearance in the coelenterates. In animals belonging to the higher invertebrate phyla, a definite nervous system in the form of ganglia and the nerve cord is present. The nervous tissue, of which the nervous system is formed, in made up of nerve cells or *Neurons* each of which is the morphological unit of the nervous system.

In vertebrates, the nervous system becomes centralised in the form of a mid-dorsal tubular nerve cord with an anterior enlargement called the brain, and a slender elongated spinal cord. From both the brain and the spinal cord, paired nerves are given out to the different parts of the body.

Nervous System in Hydra

The nervous system in Hydra is of the simplest type. (Fig. 160). Simple nerve cells (protoneurons) are scattered all over the surface of the body between the outer ectoderm and the inner endoderm. Each protoneuron has a central cell-body, with several branched processes arising from it. These neurons are never gathered together to form ganglia. Nerve fibres run in all directions. They join the nerve fibres of other nerve cells to form a sort of a network called the *Nerve net*. Such a type of nervous system, which is made up of scattered nerve cells, is known as the *diffused* type. The stimulus received at any point on the surface is spread to all the parts of the body, thus bringing about a sudden contraction of the body.

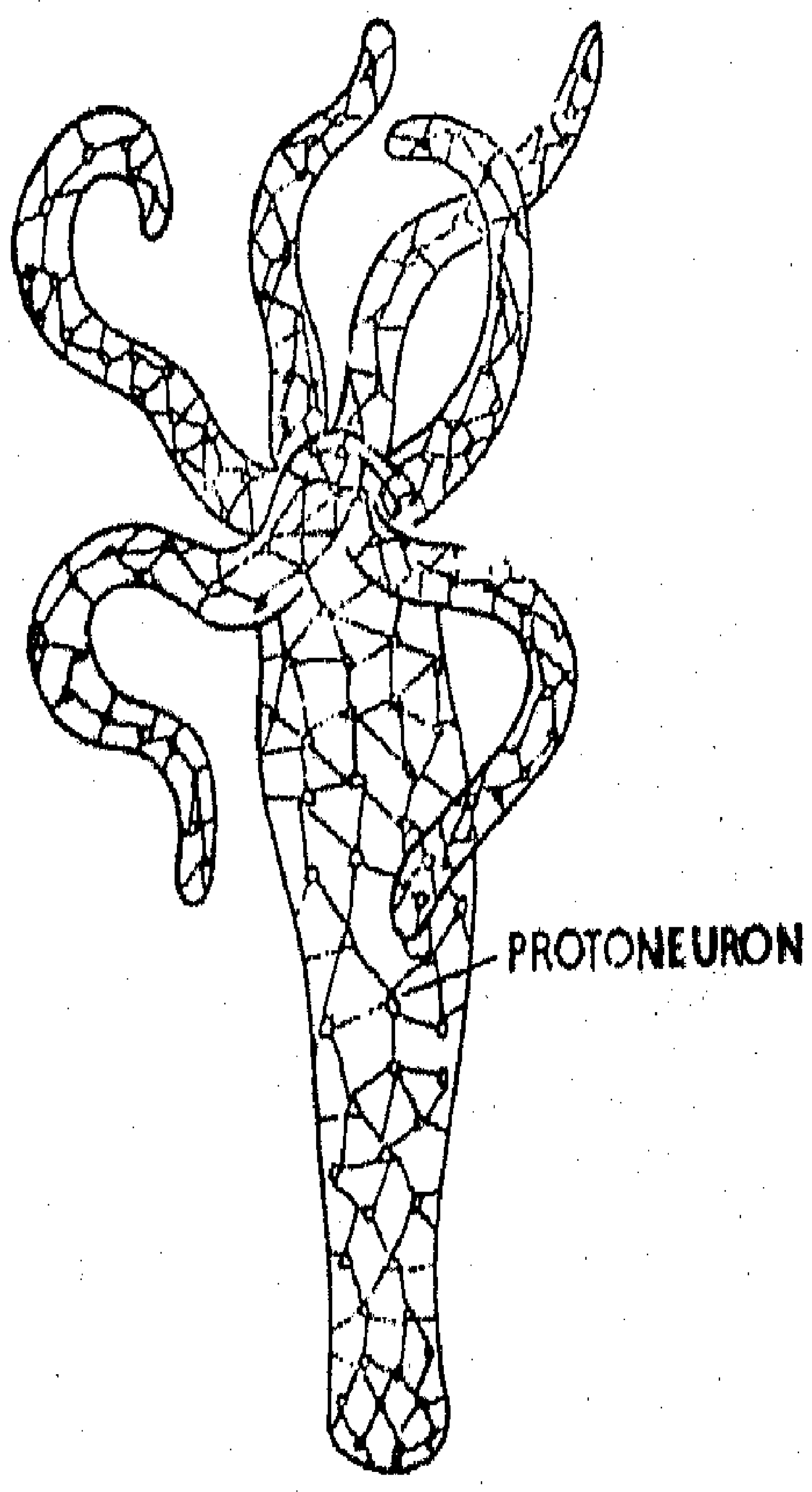


Fig. 160. *Hydra : Nervous System*

Nervous system in earthworm

The nervous system in the Earthworm (Fig. 161) is better developed than the one in the coelenterates. It consists of a double, ventral, solid nerve cord, running midventrally below the alimentary canal throughout the length of the body. In each segment, the nerve cord is swollen, presenting a pair of fused ganglia. (A ganglion is an aggregated mass of cell bodies of the neurons.) Lying on the dorsal surface of the pharynx, in the 3rd segment, is a pair of fused ganglia, called the *cerebral* or *supra-pharyngeal* ganglia (brain). This is connected to the first ganglion of the ventral nerve cord, situated in the 4th segment, by a pair of nerve connectives called *circumpharyngeal* connectives. The first ganglion of the ventral nerve cord is called the *Sub-pharyngeal ganglion*. The brain, the nerve ring and the ventral nerve cord give off nerves to the different parts of the body. Each ganglion controls the segment in which it lies.

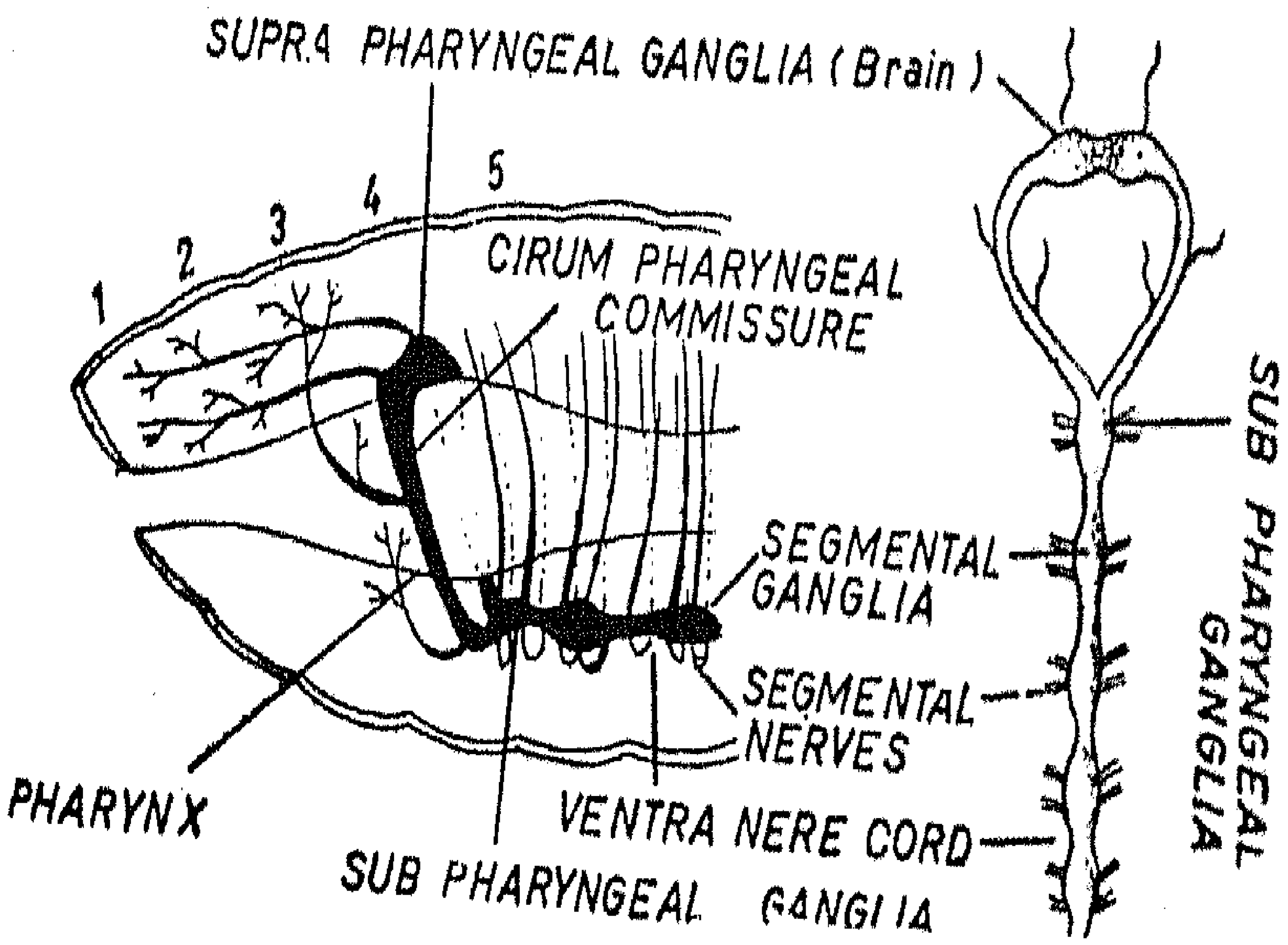


Fig. 161. *Earthworm : Nervous System*

This type of nervous system, with localisation of nerve cells in the form of ganglia and a nerve cord, is referred to as *Ganglionated Nervous System.*

Nervous system of vertebrates

The nervous system in vertebrates is highly centralised, and consists of a dorsal tubular nerve cord with the anterior enlarged portion called the brain.

For convenience, the nervous system is divisible into (1) The Central Nervous System, consisting of the brain and the spinal cord; (2) The Peripheral Nervous System, consisting of the nerves given from the brain and the spinal cord, referred to as the *cranial* and *spinal* nerves respectively; and (3) The Autonomous Nervous System controlling the various involuntary visceral activities of the body.

I. CENTRAL NERVOUS SYSTEM

The brain is safely enclosed in a bony box, the skull or cranium, and the spinal cord runs through the neural canal in the vertebral column. Both the brain and the spinal cord are covered by thin membranes of connective tissue, called the *meninges*. Fishes have a single *meninx*; but amphibians, reptiles and birds have two, while in the mammals there are three meninges. The outermost membrane is the *dura mater*. The innermost, delicate, highly vascular membrane, which is in contact with the nerve matter, is called the *pia mater*. The membrane present in between these two is called *arachnoid membrane*. Between these membranes, there is a fluid called *cerebro-spinal fluid*, which protects the brain and the spinal cord from mechanical shock. An increased secretion of this fluid, resulting from the infection with some kind of virus, causes a disease called *meningitis*.

The brain and the spinal cord are hollow and are also filled with cerebrospinal fluid. This fluid is almost similar in composition to lymph or plasma. The hollow canal inside the spinal canal is known as the *central canal*, which gets enlarged inside the brain to form large spaces called *ventricles*.

Human Brain

The human brain (Figs. 162 and 163) consists of the following regions: (1) *Cerebrum*; (2) *Brain stem*; and (3) *Cerebellum*. The brain stem comprises the *medulla oblongata*, the *pons Varolii*, the *mid-brain* and the *diencephalon*.

It is also usual to divide the brain into fore-brain, mid-brain and hind-brain.

For-brain. It consists of the cerebrum and diencephalon. It is the largest part of the human brain and is divided into two similar halves by a deep longitudinal groove or fissure. These

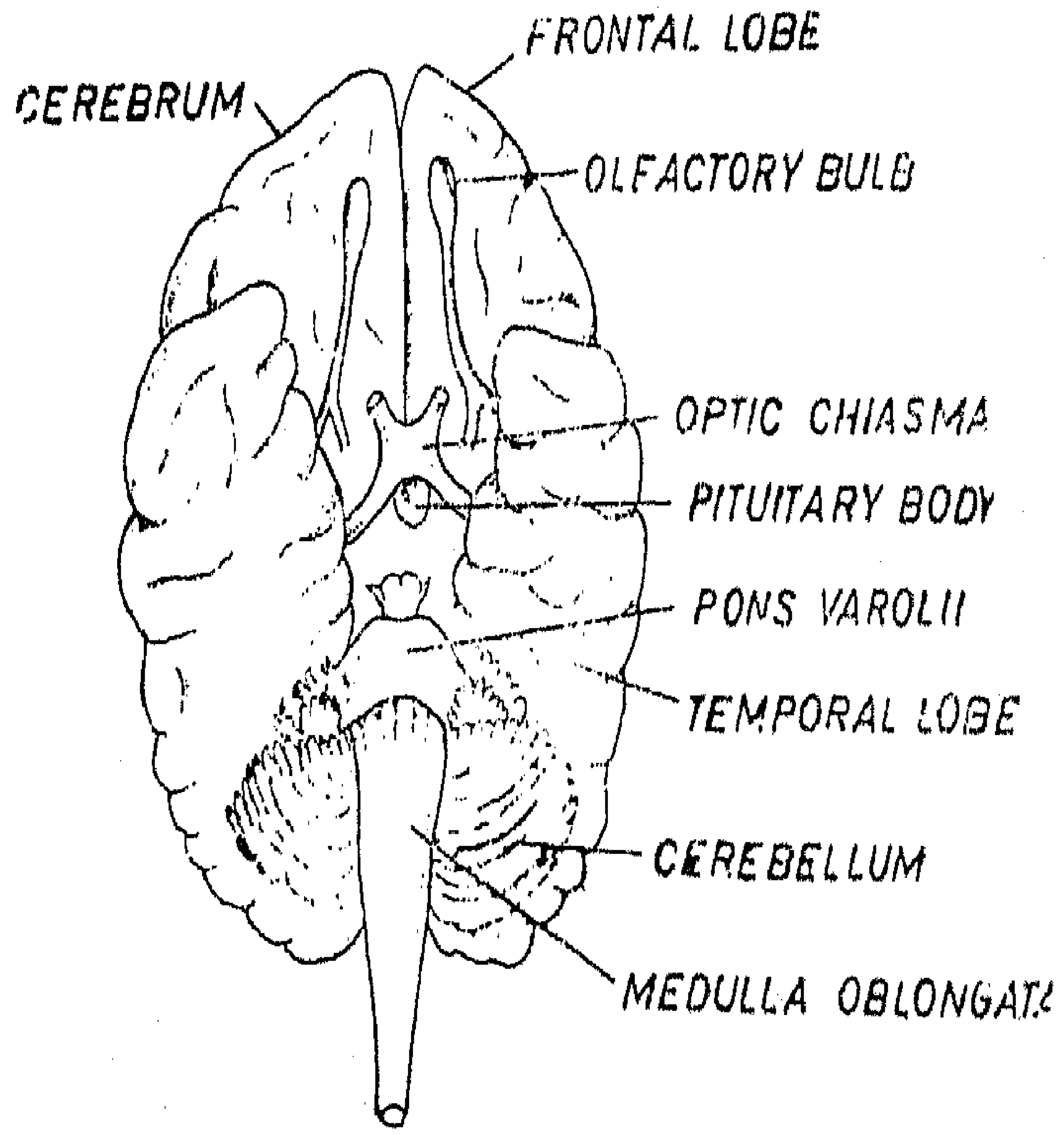


Fig. 162. *Human Brain—Ventral View*

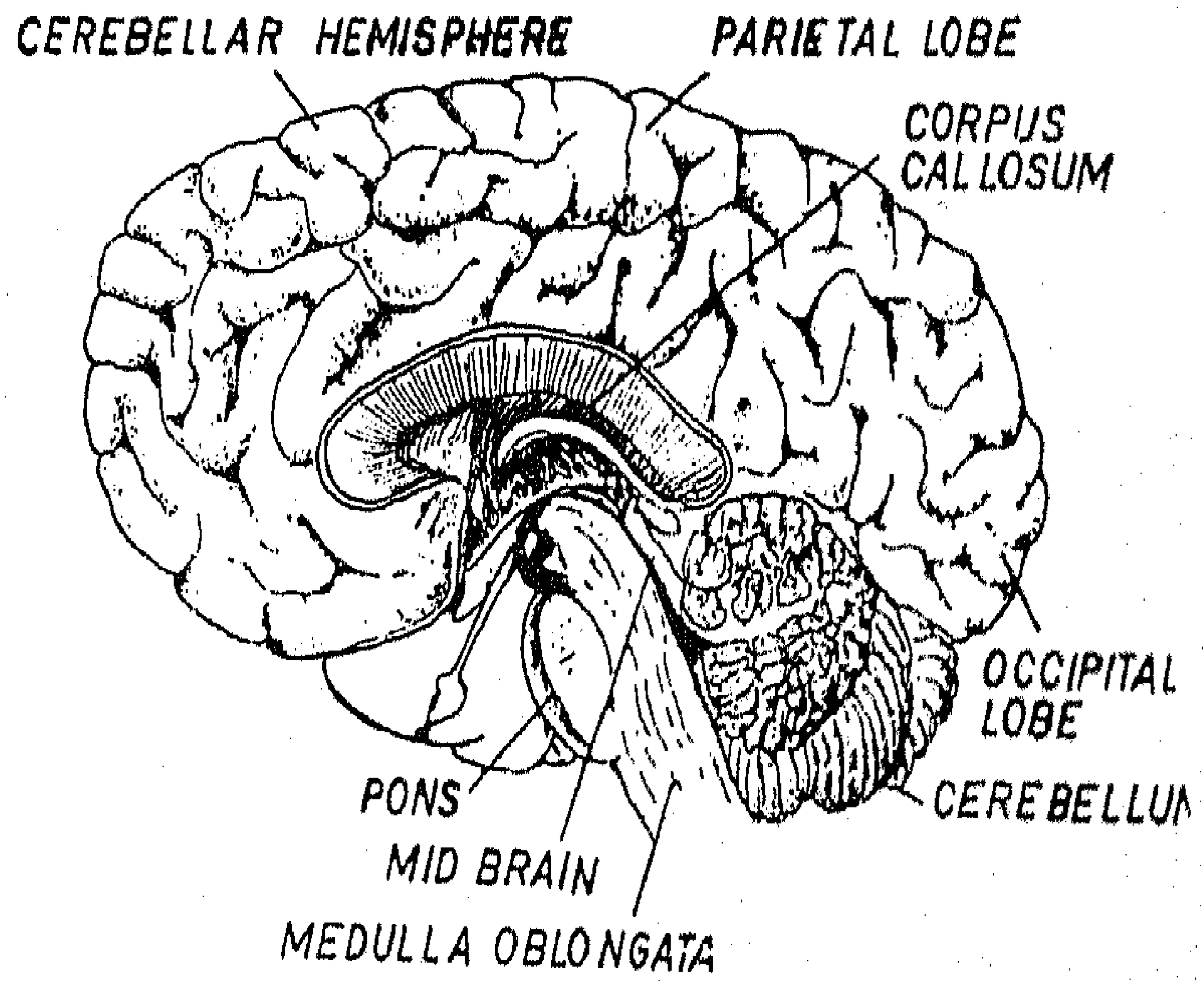


Fig. 163. *Human Brain—Vertical Section*

halves are called *cerebral hemispheres*. These two hemispheres are connected across the mid-line by a broad transverse band of

nervous tissue, the *corpus callosum*, which is a characteristic feature of the mammalian brain. The cerebrum has two distinct regions, the outer one made up of grey matter or cerebral cortex, and the inner one of white matter surrounding the ventricle. The cortex is thrown into a large number of folds or convolutions forming distinct ridges or gyri (singular, *gyrus*), separated by grooves or creases or *sulci* (singular, *sulcus*). When the sulci are deeper, they are normally referred to as fissures. Each cerebral hemisphere is further divided by deep furrows into several distinct lobes, such as frontal, parietal, occipital and temporal. Deep within these lobes are situated aggregations of grey matter forming sub-cortical centres, which control such activities as speech, taste, smell, hearing etc.

The cerebrum is considered to be the seat of intelligence, memory, reasoning, learning and will. It is associated with such feeling as pleasure, pain, fatigue, fear etc. Centres for sight, smell, taste, speech, and hearing are situated in the cerebrum. Thus the better development of the cerebrum has given to man his present status as the most superior and highly evolved animal.

Diencephalon. It is the next region of the fore-brain, which is almost involved inside the cerebral hemispheres by reason of their increased development. It consists of two large aggregations or lobes of grey matter, called the *thalami*, below which is the *hypothalamus*. This region consists of nervous structures separated by a small fissure from the optic thalamus. From the roof of the diencephalon is given out the *pineal* body, which is a solid organ and lies between the thalami. The *infundibulum* arises from the floor of the diencephalon, to which is attached posteriorly the *pituitary body*. The pituitary gland is a small but very important endocrine gland, which is called the master gland of the body because its hormonal secretion has a greater influence on the various physiological processes and development of the body and also because it controls the activity of other endocrine glands.

The olfactory lobes are poorly developed in the human brain. The two olfactory tracts arise from the ventral aspect of the cerebrum, and each ends anteriorly in an olfactory bulb.

Mid-brain. It is a very short and narrow region of the brain between the fore-brain and the hind-brain. Due to the extensive development of the cerebrum, it is hardly seen from the outside. It consists of (1) the *Crura* or cerebral peduncles in the form of two thick bundles of nerve fibres on the floor and extending into the right and left cerebral hemispheres ; (2) the *Corpora quadrigemina*, which are developed as a fourlobed structure from the roof of the mid-brain. The optic lobes are four in number, forming **Carpora quadrigemina**. The optic nerves arise from the ventral surface of the mid-brain and cross each other to form the *optic chiasma*.

The mid-brain is concerned with the equilibrium and co-ordination of the visual and auditory reflexes.

Hind brain. It consists of the *cerebellum*, *pons Varolii*, and *medulla oblognata*.

Cerebellum. It is also known as the lesser brain, and consists of two lateral halves, the cerebellar hemispheres, joined together by a central portion, the *vermis* which is transversely ridged. Like the cerebrum, it has an outer cortex of grey matter and an inner region of white matter. The cerebellum is concerned with equilibrium and brings about the co-ordination and control of various muscular activities of the body.

Pons Varolii. It is a band of nervous tissue lying in front of the medulla oblongata and connects the cerebellar hemispheres ventrally. The nerve fibres going to the cerebrum cross each other in this region. In the pons, the white matter is out-side and the grey matter inside. It is concerned with the heat regulation in the body.

Medulla Oblongata. It is the hindmost and most important part of the brain, because the centres which govern the various vital activities of life such as heart beat, circulation, respiration, etc., are situated in it. Therefore, any injury to this part results in instantaneous death.

Spinal Cords. It is the tubular portion of the nervecord after the brain which runs down the neural canal. (Fig. 164). It tapers into a slender *filum terminal* which, together with a bunch of roots of spinal nerves, looks like a horse tail-and it is known as *cauda equina*.

Running on both the mid-dorsal and mid-ventral line of the spinal cord is a longitudinal fissure, respectively known as the dorsal and ventral fissures. The ventral fissure is deeper than the dorsal. The presence of these two fissures partly divides the spinal cord into-two lateral halves. From either side of the spinal cord are given out the spinal nerves.

The cross-section of the spinal cord (Fig. 164) shows that it contains a *central canal*. The *grey matter* surrounds the central canal and the *white matter* surrounds it on the outer side. The grey matter is disposed of in an H-shaped manner, and produced dorsally into two horns and ventrally into two ventral horns. The grey matter is formed by the aggregation of the cell bodies of the neurons, which constitute the nervous tissue. The white matter is formed by the collection of the nerve fibres of the neuron.

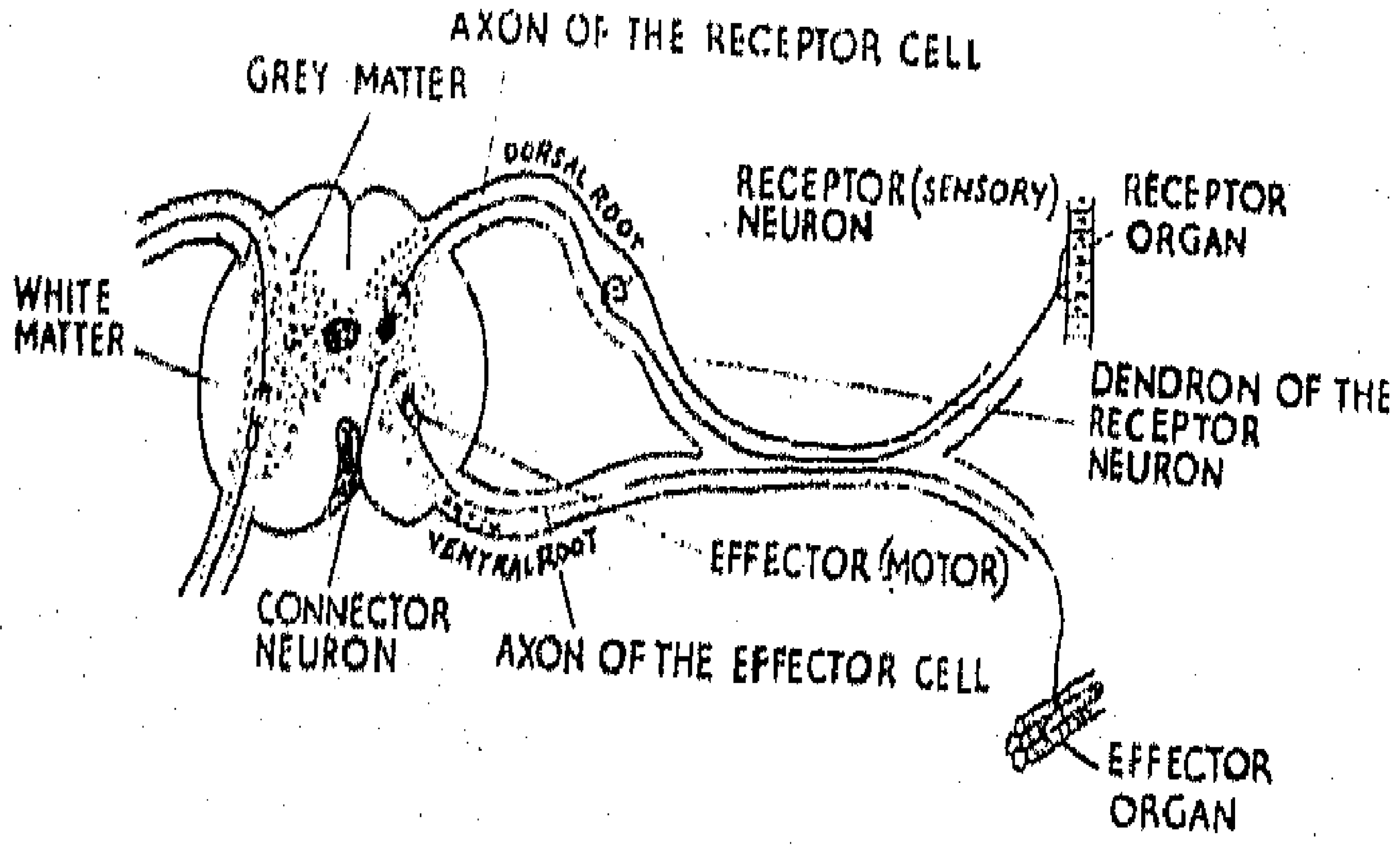


Fig. 164. *T. S. Spinal Cord ; Reflex arc*

The spinal cord acts as the path for the conduction of nervous impulses to and fro between the brain and the different parts of the body. It also brings about various *reflex actions* independent of the brain.

II. PERIPHERAL NERVOUS SYSTEM

It consists of the cranial nerves given from the brain and the spinal nerves from the spinal cord.

Twelve pairs of cranial nerves are given out from the brain in man as well as in all Mammals, Aves and Reptiles. (Only ten pairs are present in Pisces and Amphibians.) Most of the cranial nerves supply the different organs in the region of the head, face and neck. Only the tenth or the *vagus* nerve supplies the distant organs in the chest and the viscera in the abdominal region.

Thirty-one pairs of spinal nerves are given out in man. The number of spinal nerves in any vertebrate is the same as the number of vertebrae present in its vertebral column.

Each spinal nerve originates by two roots, (i) the dorsal root, arising as a continuation of the dorsal horn of the grey matter and (ii) the ventral root, which is the continuation of the ventral horn. The dorsal root bears a swollen ganglion, the dorsal root ganglion. The two roots join to form a spinal nerve, before the latter emerges out of the neural canal into the body cavity.

Reflex action. Normal actions, resulting from response to external stimuli, are always under the control, and with the full knowledge, of the brain. But most of the simple movements can occur without the intervention of the higher centres. In this respect, the action is done spontaneously by the spinal cord.

The spontaneous response to the stimulus is called *Reflex action*, an excellent example of which is the jerking of the knee if the bent knee is hit just below the knee-cap. Other examples are closing of the eyelids with the approach of any object suddenly coming in front of them, and a sudden withdrawal of the hand if it falls on a hot object. Some of the actions like swimming, cycling etc., which require great concentration and effort till they are mastered, later become merely reflexes.

Reflex Arc. It is the path way, composed of neurons, followed by the stimulus originated at the receptor organ (like the skin) to reach the central nervous system and by the response to reach the effector organ, like the muscles. (Fig. 164).

Normally, three neurons are involved in a single reflex arc. The neuron, with its cell body located in the dorsal root ganglion, is a *sensory* or *afferent* or *receptor* neuron, with its long dendron commencing from a sense receptor (*e. g.*, skin) The axon of the sensory neuron extends into the spinal cord, where it establishes a communication (*synapse*) with the dendron of the *adjustor* or *intercalary* or *connector* neuron, which lies within the cord. The axon of this neuron makes a synapse with the third neuron, a *motor* or *efferent* or *effector* neuron, lying in the ventral horn of the grey matter. The axon of this neuron extends out from the cord through the ventral root to end in an effector organ, like a skeletal muscle fibre. Thus, any chain of neurons, leading from a receptor to an effector (muscle or gland), is a *reflex arc*, and the action that results, involving such an arc, is a *reflex action*. Reflex action, therefore, is defined as any action brought about by an effector neuron due to the stimulation of the receptor neuron. The reflex arc is rarely as simple as explained here. It involves not only the sensory and the motor neurons, but also several neurons which have connections up and down the spinal cord and lead to the other parts of the central nervous system, including the cortex of brain.

III. AUTONOMIC NERVOUS SYSTEM

The autonomic nervous system functions independently of the central nervous system. All the visceral organs like the heart, the stomach, the intestine, the digestive glands, etc., are innervated by this system, which consists of two divisions, the sympathetic and parasympathetic.

Sympathetic nervous System. It consists of a pair of ganglionated nerve cords, running on either side of, and parallel to, the dorsal aorta. Sympathetic ganglia give off post-ganglionic nerve fibre to the different visceral organs.

Parasympathetic nervous system. It consists of nerves that come from the visceral neurons situated in the brain and the sacral region of the spinal cord, and their fibres flow through the vagus nerve and the spinal nerves respectively.

The visceral organs for the most part receive a double supply of nerve fibres from these systems. In general, the actions of the sympathetic and parasympathetic nerves are different and commonly antagonistic (*i. e.*, of opposite nature). For instance, in the heart, the parasympathetic nerves slow down or inhibit its action, while the sympathetic nerves accelerate the heart beat. The smooth muscles of the viscera and the blood vessels are under a similar dual control.

Brain of other Vertebrates

The brain in all other vertebrates is based on the same plan as the brain of man. The only differences are in size and complexity, which are related to the degree of development of the various faculties in the individual.

The brain in these animals can also be conveniently divided into the following distinct regions :

(i) The fore-brain formed of olfactory lobes, cerebrum and diencephalon ;

(ii) The mid-brain composed of the optic lobes ; and

(iii) The hind-brain composed of the cerebellum and the medulla oblongata.

The corpus callosum and pons Varolii are missing in all vertebrate brains other than those of mammals.

Brain of Frog

Fore brain (Fig. 164) It has a pair of fused olfactory lobes at the anterior end, followed by the cerebrum, which is divided by a median longitudinal fissure into two cerebral hemispheres. The surface of the cerebrum is smooth and without any folds. Posterior to the cerebral hemispheres is a small diamond-shaped area, the diencephalon. From its roof is given out a pineal stalk bearing a pineal body at its tip. From the floor of the diencephalon is given out ventrally the infundibulum, to which is attached posteriorly the pituitary body. Dorsally, the roof is covered by a vascular membrane, the *anterior choroid plexus*, which supplies nourishment to the anterior parts of the brain.

Mid-brain. It consists of two large well-developed optic lobes, each of which gives off ventrally the optic nerve. The two optic nerves cross each other in front of thé infundibulum and proceed to supply to the eye of the opposite side. This X-shaped crossing is called *optic chiasma.*

Hind brain. It includes the cerebellum, which is a small flap-like structure projecting out dorsally from the mid-brain. The medulla oblongata is the last part of the brain and as usual controls the vital functions of the body.

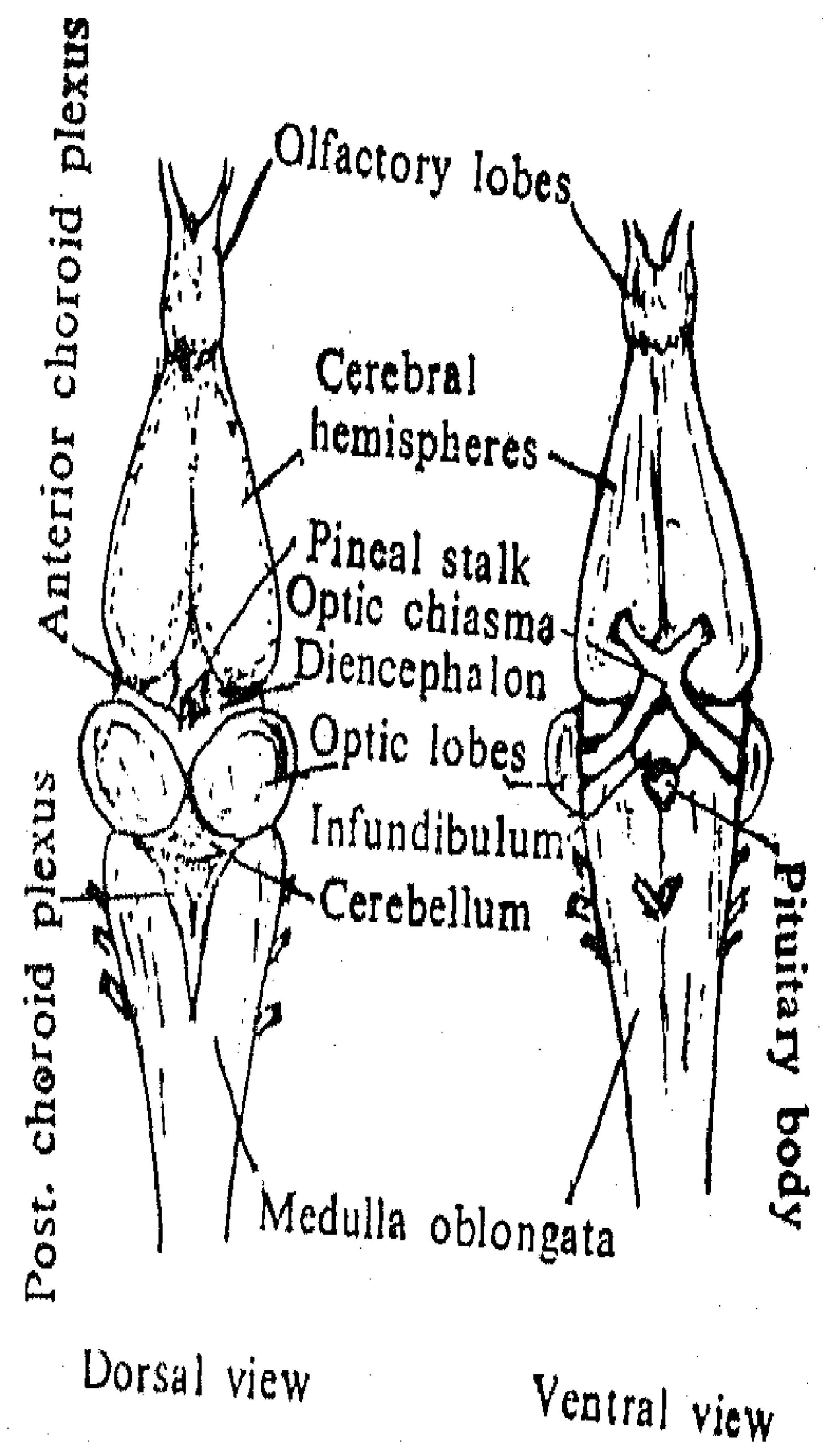


Fig. 165. *Frog Brain*

Brain of Rabbit

The *Cerebral hemispheres* are well-developed, (Fig. 166) and show few convolutions on the surface. Anteriorly are present a pair of large club-shaped olfactory lobes. This accounts for the acute sense of smell in these animals. Each olfactory lobe extends posteriorwards on the ventral aspect of the cerebrum as an *olfactory tract*, which is posteriorly enlarged to form the *olfactory tubercle*.

The *diencephalon* is situated behind the cerebrum, carrying the pineal stalk on the dorsal surface and the infundibulum and the pituitary body on its ventral side. The anterior choroid plexus is present on the roof.

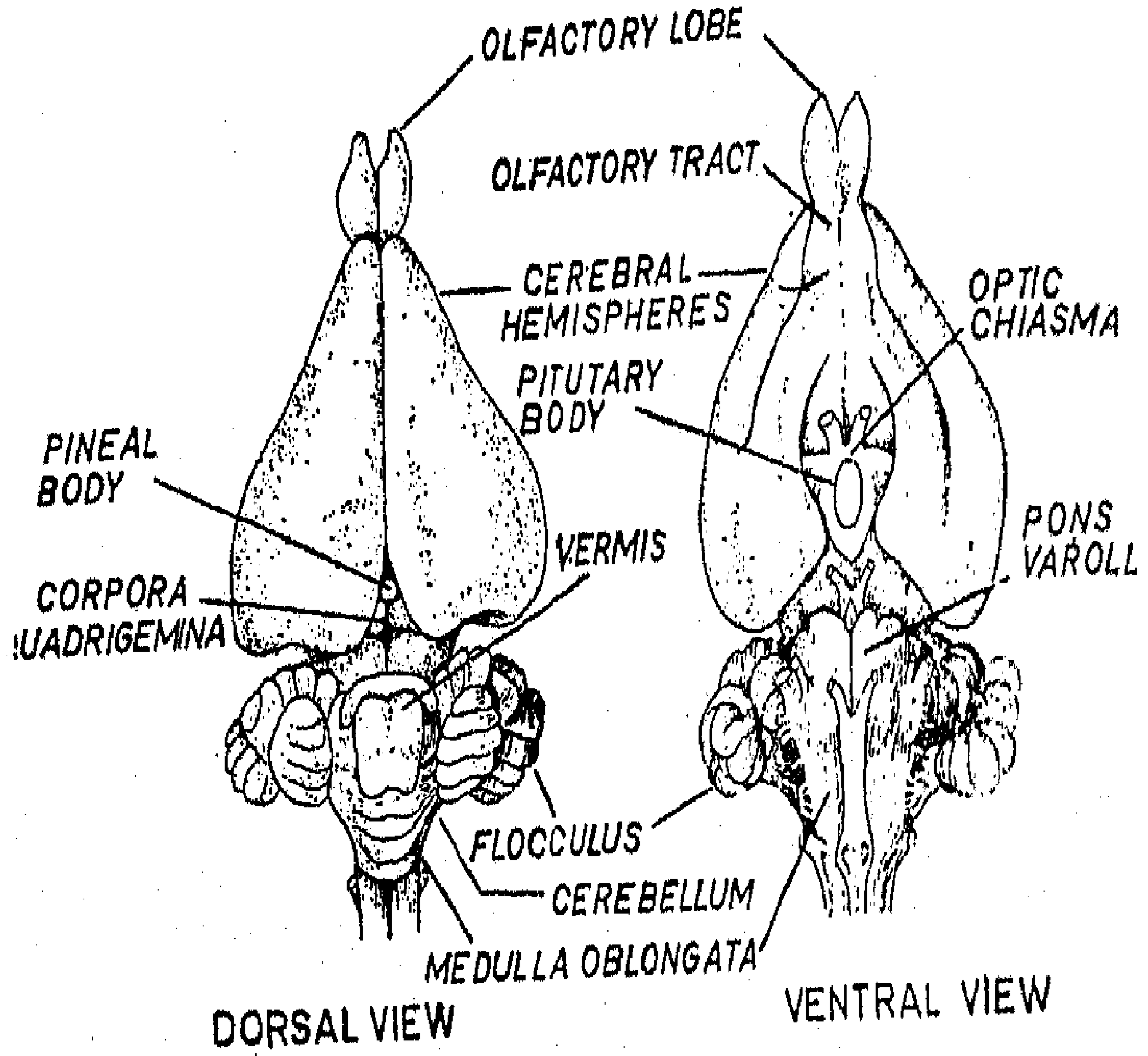


Fig. 166. *Rabbit Brain*

The *mid brain* is made up of four lobes, which have been formed by the division of the two optic lobes. Together they are called *corpora quadrigemina.* The two optic nerves, arising ventrally from these lobes, cross each other to form the optic chiasma in front of the infundibulum.

The *cerebellum* is of large size, divided into a *median vermis* and two lateral cerebellar lobes. To each lobe is attached a smaller lobe known as the *flocculus* (plural, *floculi*). The surface of the cerebellum is thrown into several folds or convolutions. On the ventral aspect is transversely present the pons Varolii, connecting the different lobes of the cerebellum.

The medulla oblangata is the last part of the brain and, as usual, controls the vital functions of the body.

SUMMARY

1. The nervous system coordinates and controls the various activities of life.
2. Neuron or the nerve cell is the unit of nervous system.

3. The nervous system in hydra is the simplest. It forms a nerve-net and is of the diffused type.
4. In earthworm it is slightly more evolved, and consists of a nerve ring and a double nerve cord running throughout the length of the body.
5. The nervous system thus is ganglionated and linear.
6. In frog the brain is differentiated into (a) Forebrain (b) Mid-brain and (c) Hind brain.
7. In rabbit and man also the brain consists of the same three regions mentioned above.
8. In rabbit, the olfactory lobes are well developed. The cerebellum is large and divided into vermis and the two lateral lobes are called floculi.
9. In man cerebrum is the largest part of the brain which accounts for the high degree of intelligence.
10. The two parts of the cerebrum are connected by a nervous tissue called the Corpus Callosum.
11. The olfactory lobes in man are poorly developed.

BIOLOGICAL WORDS

Neuron
Ganglion
Cerebrum
Medulla oblongata
Cerebellum
Corpus callosum
Pons
Corpora quadrigemina

QUESTIONS

1. Describe the human brain and state the functions of its various parts.
2. Write short notes on:—
   (a) Nervous system of Earthworm, (b) Nerve net, (c) Reflex action, (d) Brain of Frog.

15

Sense Organs

Animals, which are more advanced in evolution, are in a position to make more efficient responses to their environment, more accurately and more promptly, than those which are primitive. This particular favourable advance makes them better suited to the changing environment in which they live.

The animals are provided with special organs of reception, the *receptor* or *sense organs*. A *sense organ* is specialised to receive one or the other kind of stimuli from the changing environment, either external or internal.

A *stimulus* is any influence, either external or internal, which induces in the sense organ an impulse that is carried along the sensory nerve to the central nervous system. Depending upon the nature of the incoming impulses, the central nervous system brings about a *response* through an effector organ. Like the muscles and the secretory glands.

There are mainly five different kinds of stimuli, namely, (i) touch (or tactile); (ii) taste (or gustatory); (iii) smell (or olfactory); (iv) vision (or visual) and (v) sound (or auditory).

The organs concerned with the reception of these stimuli are, respectively: (1) The skin; (2) The tongue; (3) The nose; (4) The eye; and (5) The ear.

Skin

The organ concerned with the sensation of touch is the skin, which is not only sensitive to *touch* but also to *pressure, pain* and differences in *temperature*.

The skin (Fig. 167) is made of two layers, the outer epidermis and the inner dermis. The dermis is wavy, and sends projections in the form of dermal *papillae* beneath the epidermis. It contains specialised sensory cells, provided with nerve endings of sensory nerves. These specialised receptor cells are of different types. Some are sensitive to touch, a few to pressure, and some others are capable of receiving the stimulus of temperature, etc. The tactile receptors occur over most of the exterior surface. Some are free nerve endings, and others are in the form of groups of cells enclosed in a tiny capsule of connective tissue, and are provided with sensory nerve terminations. These capsules are known as *touch corpuscles*.

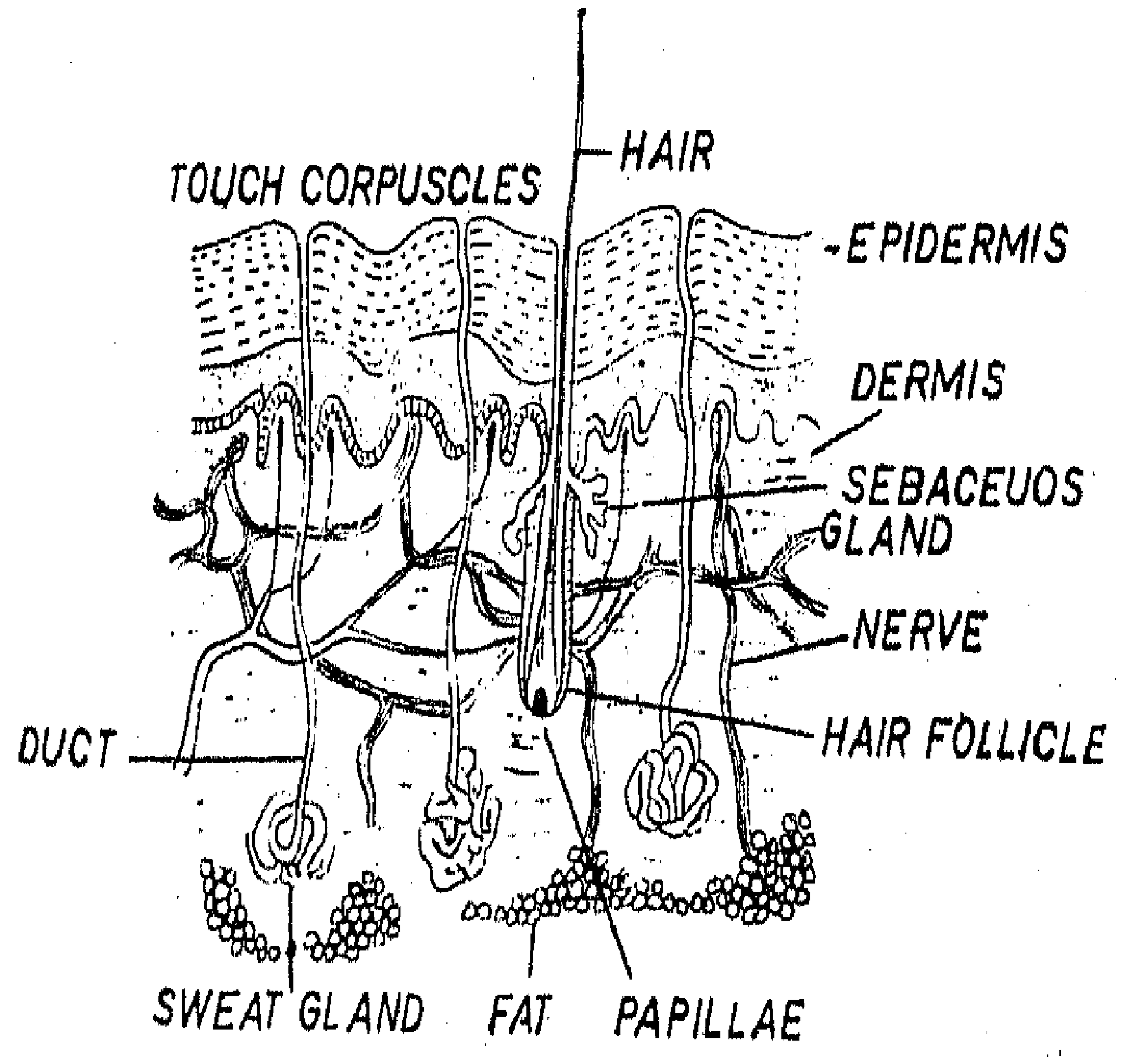


Fig. 167. *Human Skin V. S.*

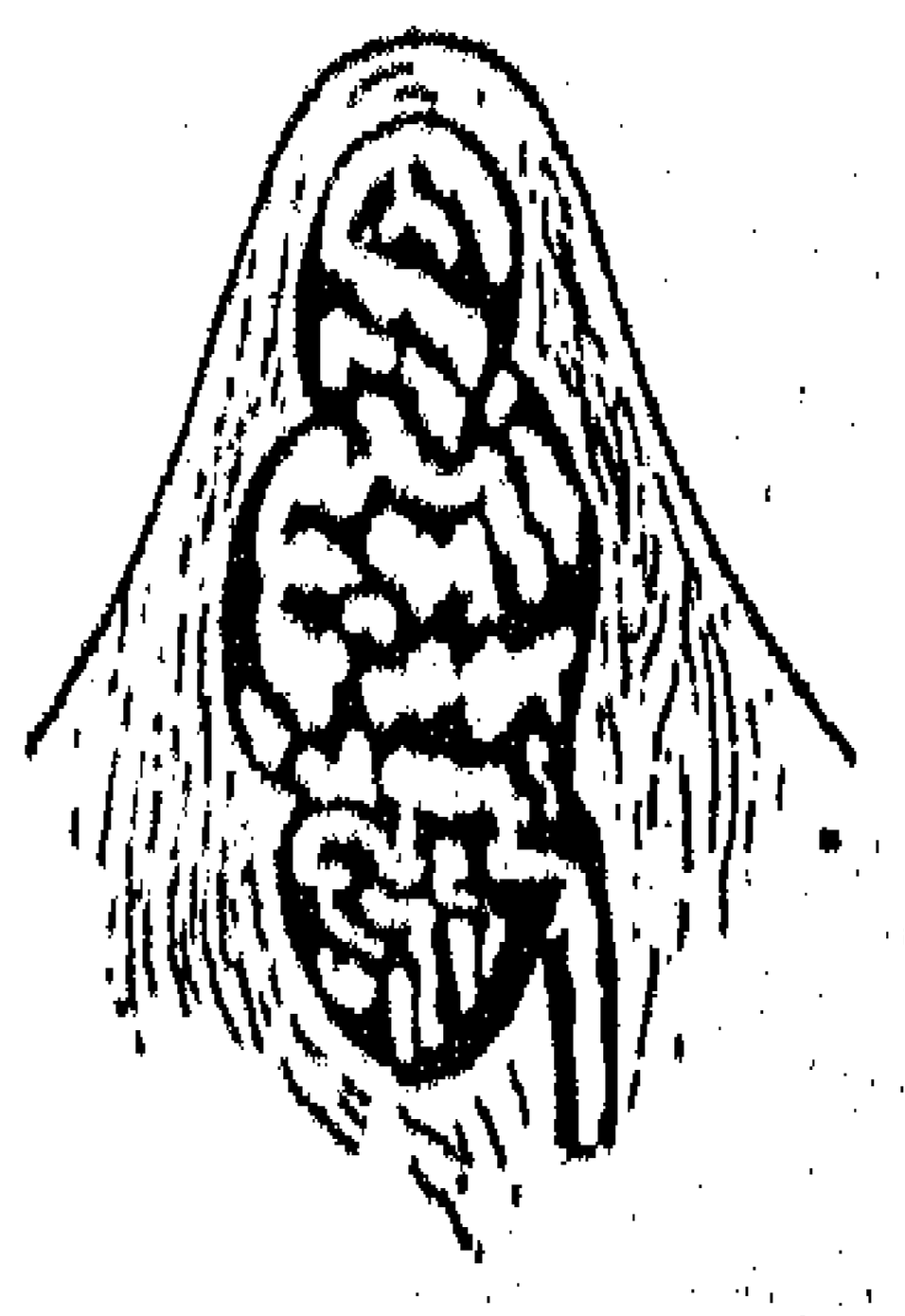


Fig. 168. *Touch Corpuscle*

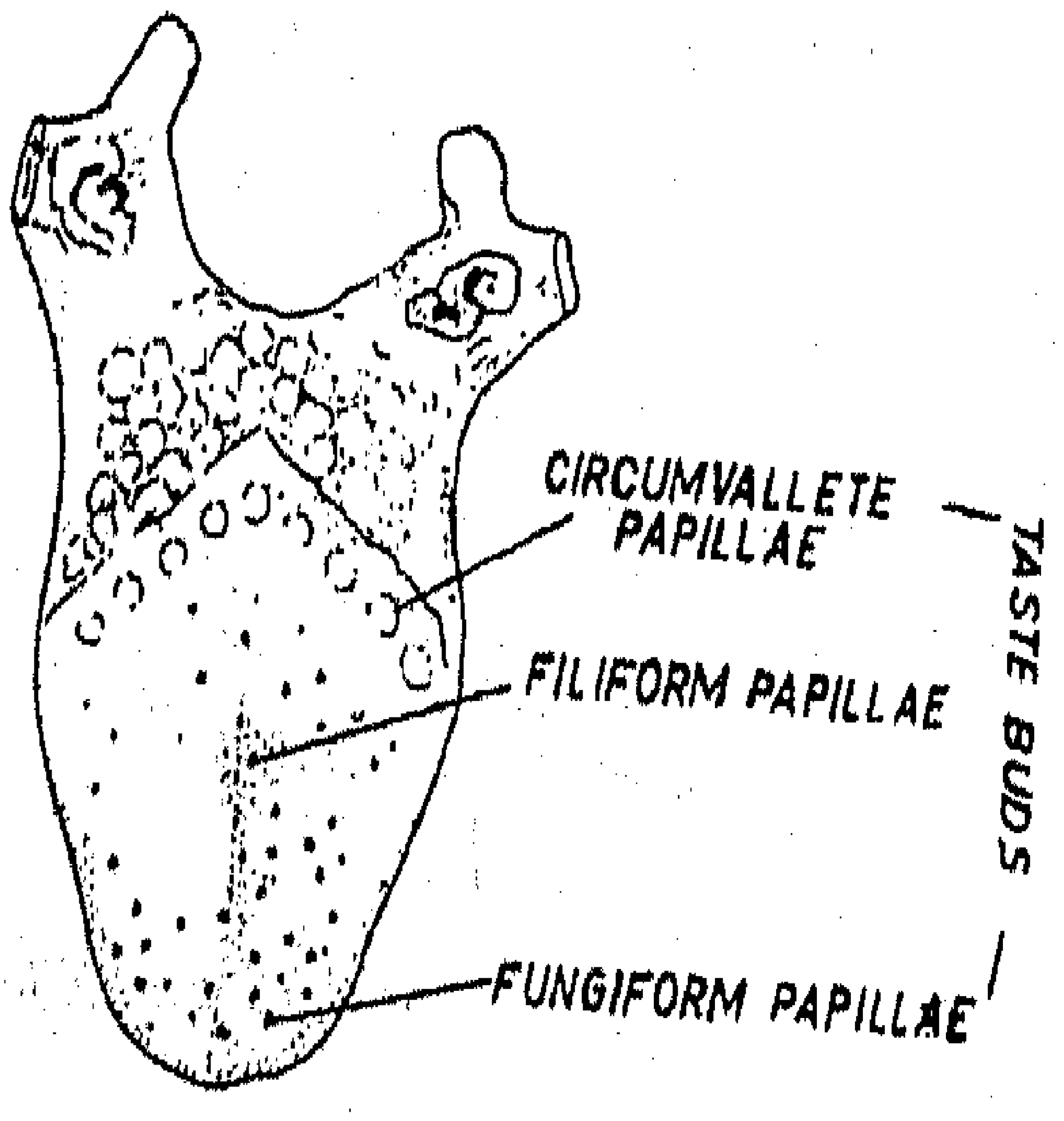


Fig. 169. *Tongue with papillae*

(Fig. 168), which are lodged in the dermal papillae. They are not uniformly distributed, being more restricted to the finger-tips, palm, lips, face, etc.

Tongue

The tongue is the organ which is responsible for the realisation of taste. The special receptor gustatory cells of the tongue are arranged in the form of *taste buds*. These occur on the surface of the tongue within small projections or elevations called the *papillae*. (Fig. 169). Depending upon their shape, there are three different kinds of papillae: (1) *Circumvallate*; (2) *Fungiform*; and (3) *Filiform*.

The *circumvallate* papillae are about 8 to 10 in number. They are large and flat, and arranged at the root of the tongue in the form of an inverted V. The *fungiform* and the *filiform* papillae are found scattered all over the surface of the tongue; but the fungiform are more numerous at the tip and the sides of the tongue, and the filiform in the middle region. Different kinds of tastes are realised at different regions of the tongue. The tip of the tongue is most sensitive to sweetness, the sides to sourness, the tip to salty, and the back to bitterness.

The *taste buds* are small clusters of elongated sensory cells arranged in an oval capsule or pit with a small aperture at its upper pole. (Fig. 170). The upper free ends of the sensory cells are provided with sensitive hair-like processes, and their basal ends are connected to the nerve endings.

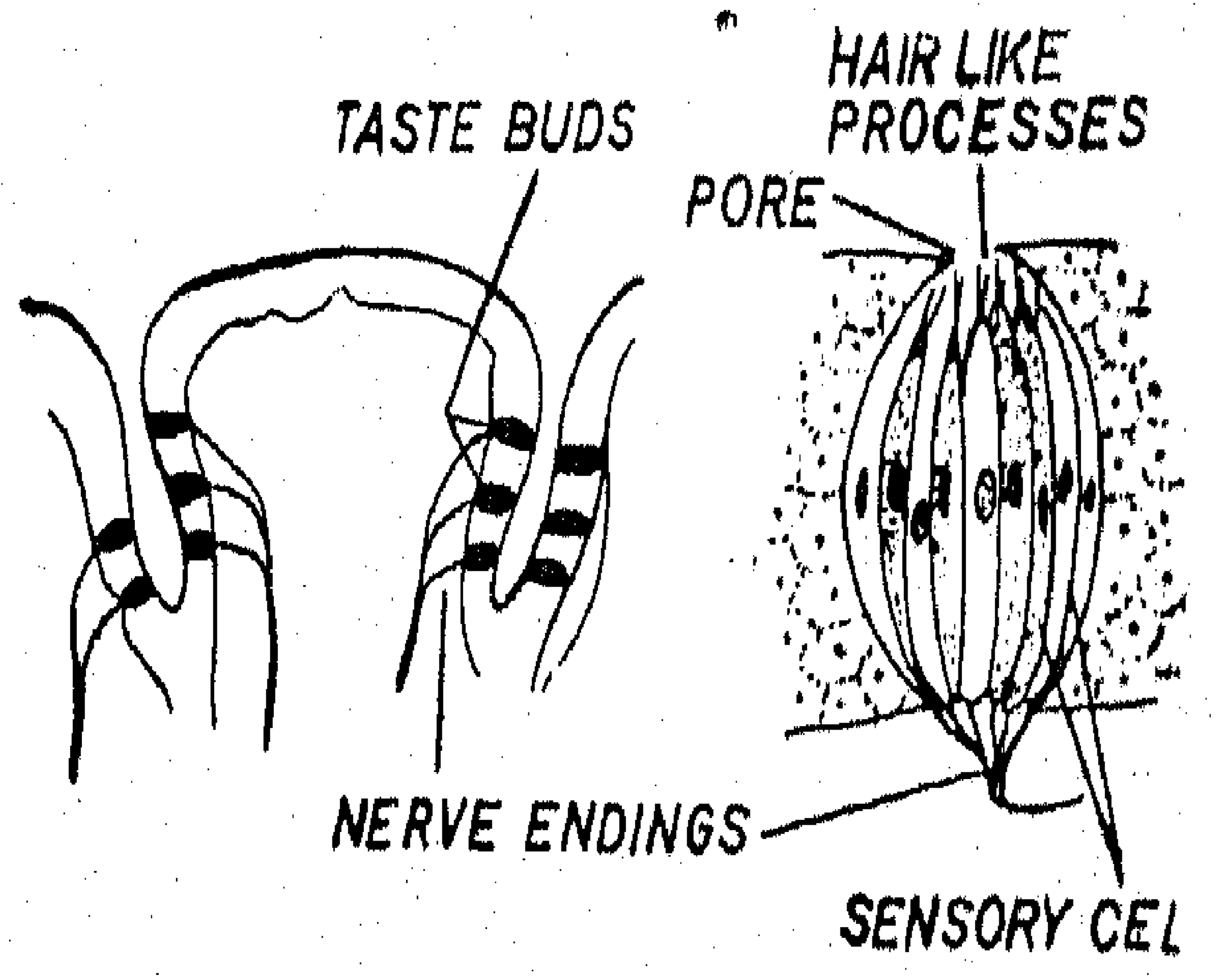


Fig. 170. *Papillae and Taste bud*

For the realisation of taste, the substance should be in solution. The particles in solution stimulate the sensitive hair-like processes, which pick up these stimuli. This stimulation is conducted to the central nervous system by the nerve endings; and the sensation of taste is realised.

Nose

The organ of smell is the nose. It has two external *nostrils* (or *nares*), each leading into a small *nasal cavity*. (Fig. 171a). The two nasal cavities are separated from each other by a vertical septum, the *nasal septum*. The nasal cavity opens into the pharynx internally by the internal nare, and is lined with the mucous membrane or the *olfactory epithelium*, which contains specialised receptor cells, the *olfactory receptors* or cells. (Fig. 171b). These cells are elongated and columnar, bearing a tuft of fine olfactory hairs at their distal ends. Their basal ends are continued as *olfactory* nerve fibres, which enter the brain.

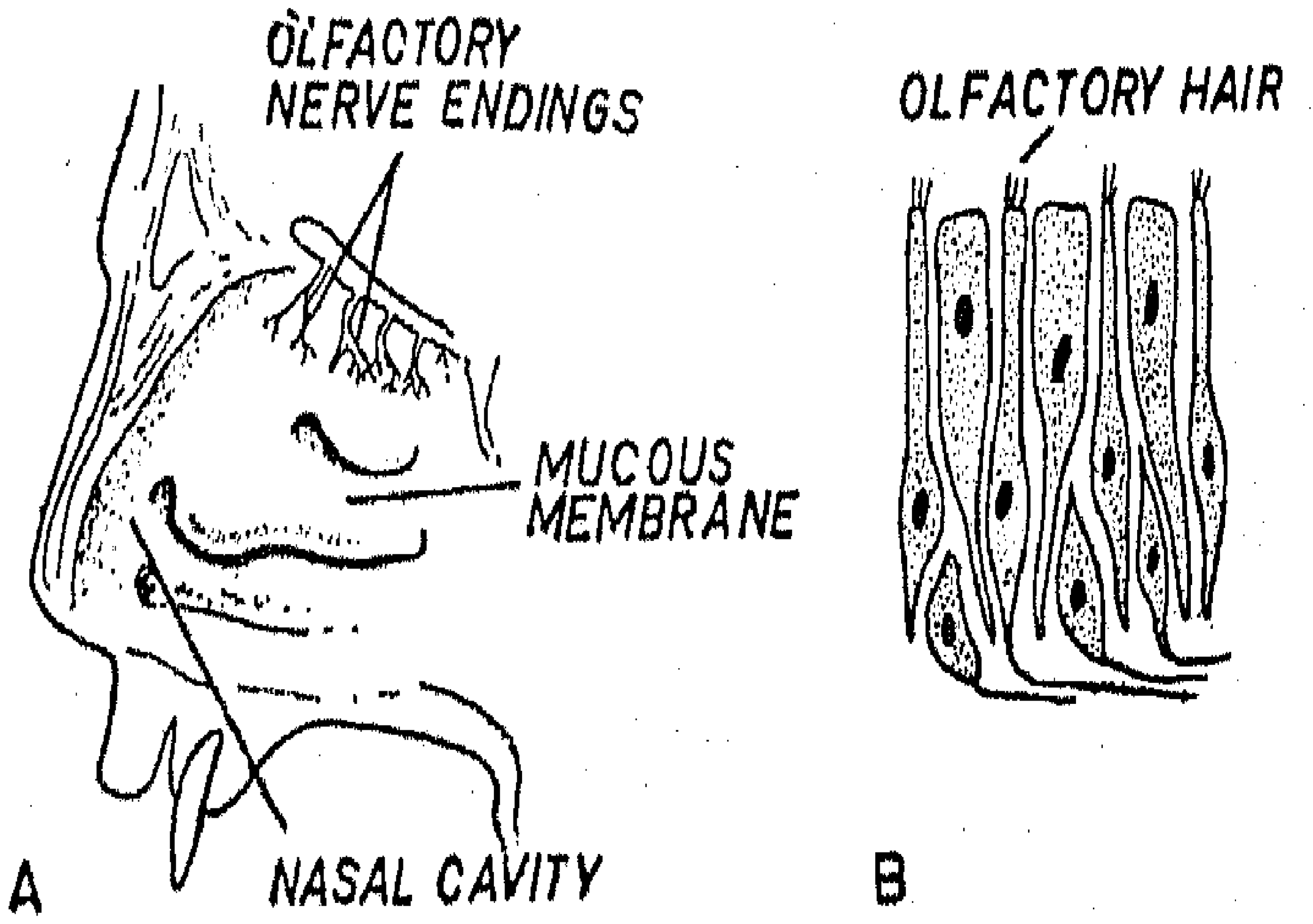


Fig. 171. *A. Nasal Cavity V. S.* *B. Olfactory receptors*

Like taste, the sense of smell or olfaction also results from chemical stimuli. In order to stimulate the cells, the substance first goes into a vapourised or gaseous condition. Particles of this substance get dissolved in the mucus secreted by the epithelium and stimulate the receptors. The impulse is carried to the central nervous system through the *olfactory nerves*, and the sensation of smell is realised.

Eye

The eyes are the organs of vision. Each eye is a delicate spherical organ, (Fig. 172) lodged in a bony cavity called the *orbit*. On its surface, it is provided with six muscles, which not only help in its attachment but also in its rotation in the desired direction. The eye is protected from dust and intense light by a pair of eyelids, with eyelashes attached to them. The eyeball is kept moist by the secretion of tear glands, the *lacrymal glands*, which are present at the upper corner of each eye.

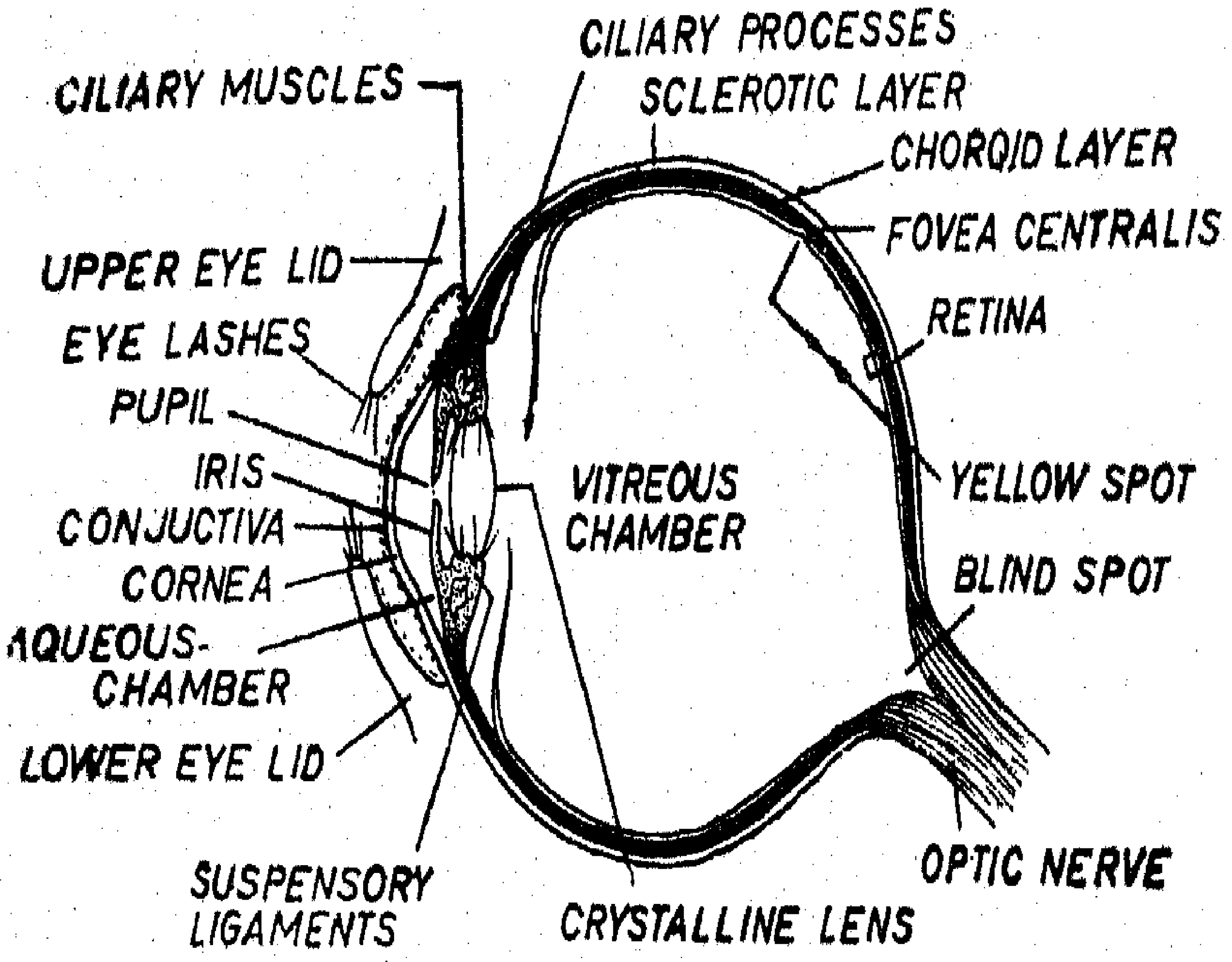


Fig. 172. *Human Eye V. S.*

The innernost epithelial lining of the eyelids is continuous in front of the eyeball. This is transparent, and is known as the *conjunctiva.*

The wall of the eyeball is made up of three concentric layers or coats: (1) The *sclerotic*; (2) The *choroid*; and (3) The *retina.*

The *sclerotic* layer is the outermost protective layer, white in colour, and is made up of tough connective tissue, supported by cartilage. It is opaque for the most part; but, in the front, it is modified to form a transparent portion, the *cornea*, which circular is devoid of blood vessels.

The choroid layer is the middle layer, which is highly vascular and darkly pigmented. It not only provides nourishment to different cells of the eye, but also acts as a dark screen, creating a completely dark lightproof chamber inside the eye. This layer continues in the front, behind the cornea in the form of a circular curtain-like disc, called the *iris*. It carries a central dilatable perforation, the pupil, which contracts in bright light, and dilates in dim-light. The iris is provided with muscles which, by regulating the size of the pupil, also regulate the amount of light entering the eye.

At the rim of the iris, the choroid layer is thickened to form the *ciliary body*, which is bound to the sclerotic layer by *ciliar muscles.* The ciliary body gives off tiny projections, the *ciliary processes.* From these processes are given out the *suspensory ligaments*, which hold between them a transparent biconvex crystaline *lens*. The lens is enclosed within a delicate membranous capsule.

Due to the disposition of the lens, the cavity of the eyeball gets divided into two unequal chambers. The smaller chamber in front of the lens is the aqueous chamber, while the larger chamber, lying

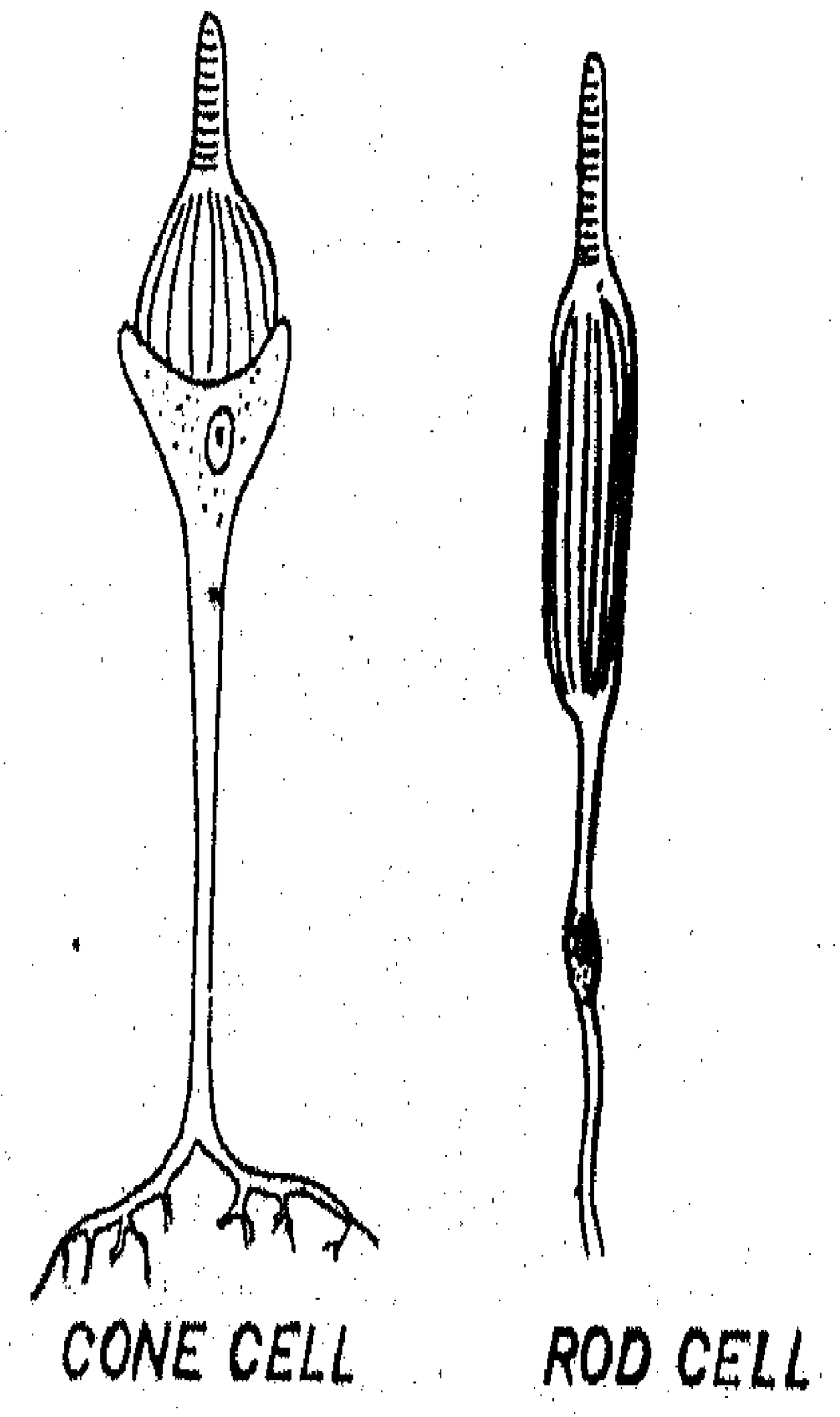


Fig. 173. *Photoreceptors*

posterior to the lens, is the *vitreous chamber*. The former is filled with a transparent watery fluid, the *aqueous humour*, and the latter with a transparent jelly-like substance, the *vitreous humour*. The latter gives the eyeball its spherical shape.

The *retina* is the innermost light-sensitive layer. It is incomplete in front and not produced behind the cornea or the lens.

It is made up of several layers of different types of nerve cells, of which the innermost layer, *i.e.*, one which is in contact with the choroid layer, is made up of specialised light receptor cells called *rods and cones*. (Fig. 173). The rods are elongated and much more numerous than the cones, and are concerned with colourless vision. The cones are cone-like cells, fewer in number, and are concerned with colour vision. These cells are connected to the nerve endings of the *optic nerve*, which enters the eyeball at an oblique angle from behind. At the point of its entry, the rods and cones are lacking in the retina. This spot incapable of making any vision is known as the *blind spot*. Slightly above the blind is a small area called the *yellow spot*, where the rods and cones are in abundance. In its centre is a minute depression known as *fovea centralis*, which is the most sensitive part of the retina.

The working of the eye. The light rays, reflected from an object, pass through the cornea, the aqueous humour, the pupil, the lens and the vitreous humour. The cornea and the lens bring about the focusing of light upon the retina. A diminished inverted image of the object is formed over it. The rods and cones are so stimulated as to create an impulse, which is conveyed to the brain through the optic nerve, and a correct vision of the object is interpreted.

The eye has the power of accommodation, that is, it can adjust itself in such a way as to always focus the image of objects at different distances on the retina. This is achieved by the flexibility of the lens. The light rays coming from distant objects are nearly parallel, while those coming from a nearer object are divergent. In order that these light rays get focused on the retina, they are required to be bent or refracted. This is achieved by altering the diameter or convexity of the lens.

Ear

The ear (Fig. 174) is a stato-accoustic organ, for some of its parts are concerned with hearing (accoustic) while others with the static sensation, namely, the balancing of the body. The ear is conveniently divided into three parts, the external the middle, and the internal.

The *external ear* includes an outer expanded structure, the *pinna* or ear-flap and a tube, the *external auditory meatus* or canal, terminating at its inner end with the *tympanic membrane*.

The pinna is flexible and supported by cartilage. The external auditory canal is a bony tube. Its internal lining is provided with hairs and wax-secreting glands, which prevent foreign bodies from getting into the ear.

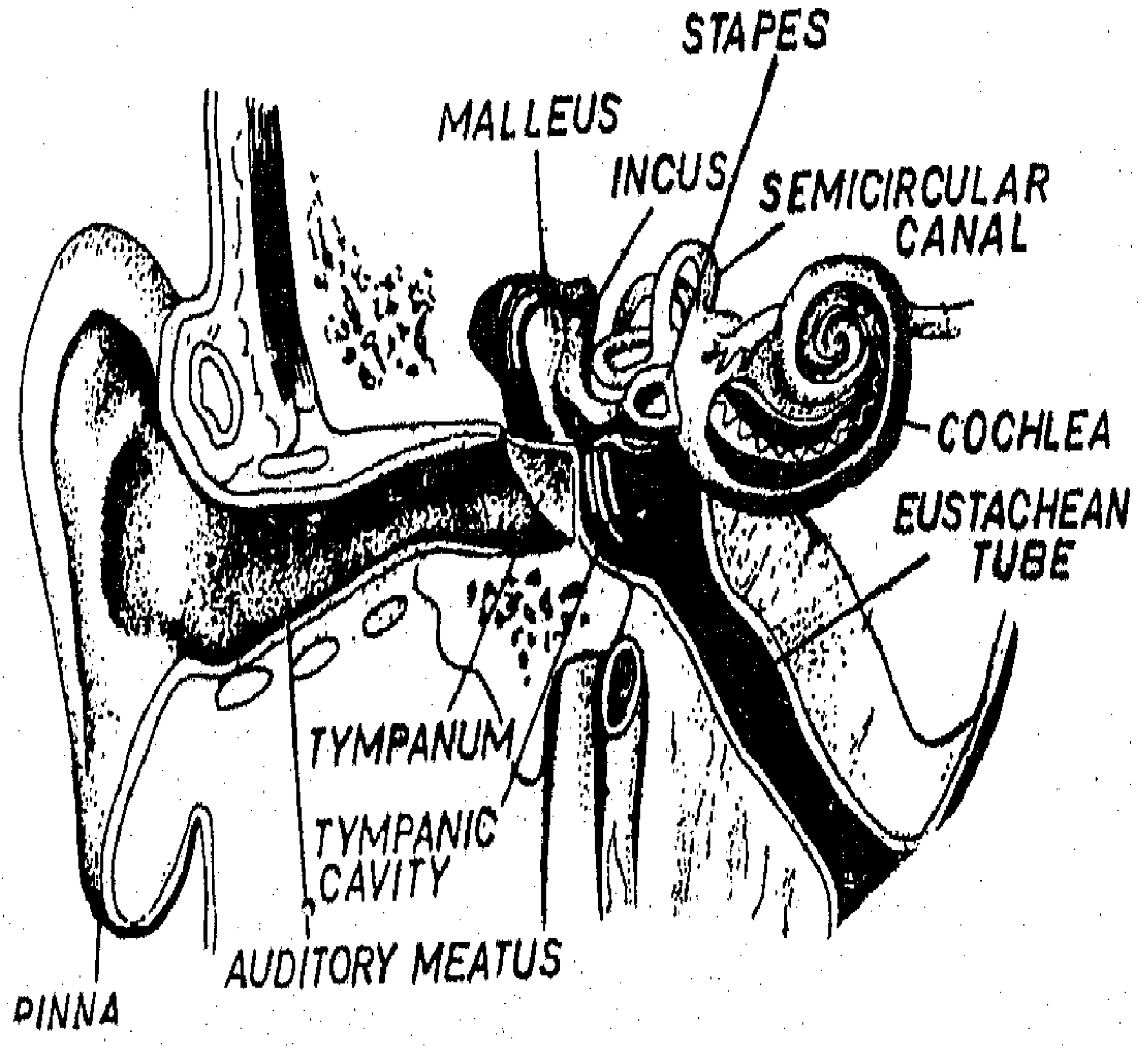


Fig. 174. *Human Ear*

The pinna serves to collect the sound waves, which are conveyed through the external auditory canal to the tympanic membrane.

The *middle ear* consists of an irregular bony cavity, the *tympanic cavity*, and a tube leading from it into the pharynx, the *eustachian tube*. A well-stretched thin membrane, tympanic membrane or the ear-drum, covers it externally, where it is connected with the external auditory meatus.

The eustachian tube serves to keep the middle ear in communication with the outside atmosphere, with the result that the air pressure on both sides of the ear-drum is equalised. This prevents the rupture of the tympanic membrane in case of sudden pressure differences in the atmosphere.

The tympanic cavity also contains a chain of 3 small movable bones or *auditory ossicles.* The outermost bone, which is connected to the tympanum, is the *malleus* (Hammer). The middle one is the *incus* (anvil) and the innermost is the *stapes* (stirrup). The stapes is connected internally to the membrane of an oval aperture, the *fenestra ovalis.* All these bones are inter-connected, and serve to transmit the sound vibrations of the ear-drum across the tympanic cavity to the internal ear.

The *internal ear* consists of a *membranous labyrinth* (Fig. 175), which is surrounded by a *bony labyrinth* of the same shape. The bony labyrinth is filled with a clear fluid, the *perilymph,* which surrounds the membranous labyrinth. The bony labyrinth has a small

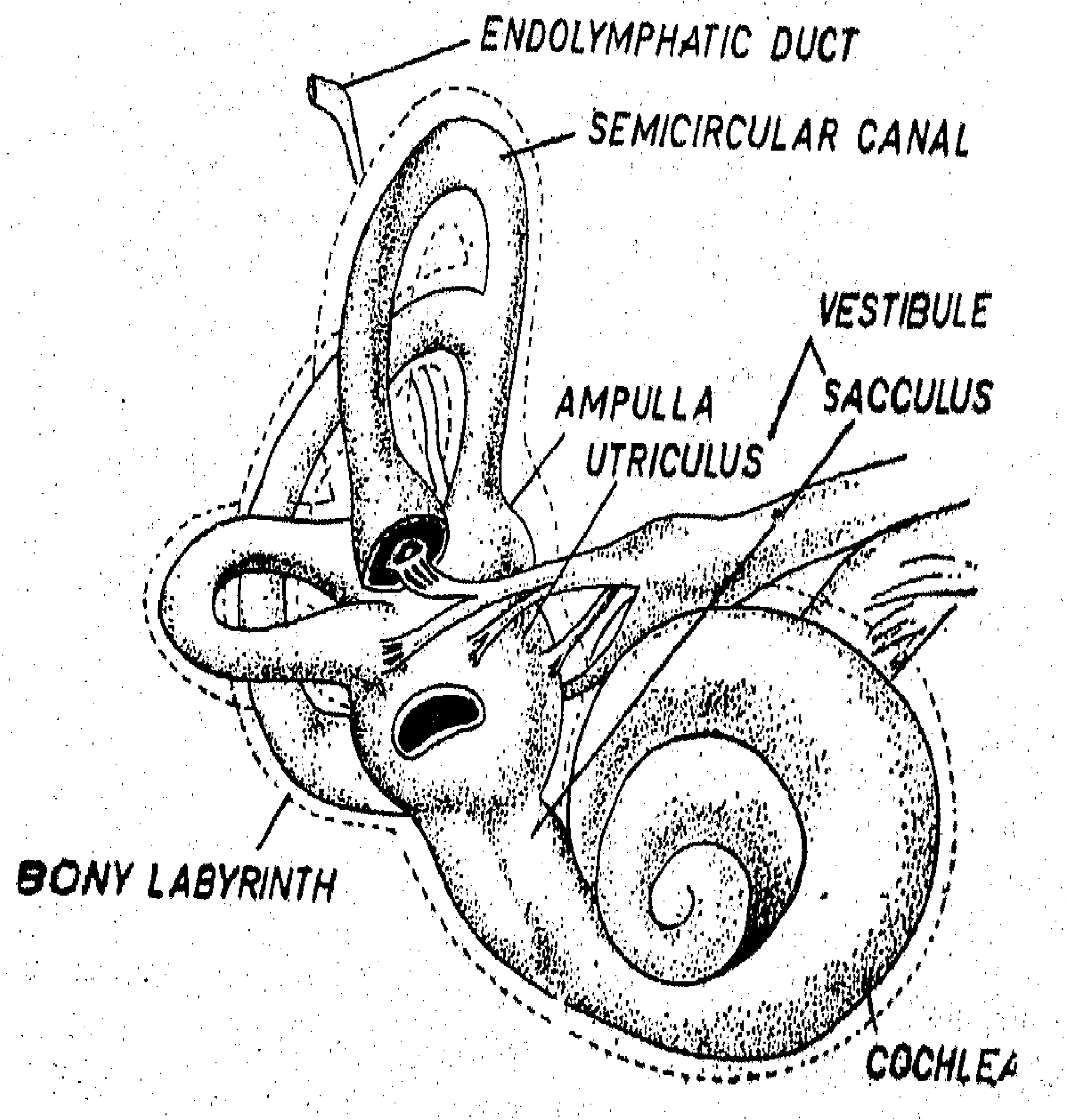


Fig. 175. *Membranous Labyrinth*

oval window covered by a membrane, to which is attached the stapes from the outside. Beneath this aperture lies another rounded aperture, the *fenestra rotunda* which is also covered by a thin membrane. The membranous labyrinth is a cartilaginous structure filled with a fluid called *endolymph,* into which are small calcareous particles, the *otoliths.* The membranous labyrinth has the following parts: (i) Two small structures, the upper *utriculus* and the lower *sacculus*; (ii) Three semi-circular canals attached to the utriculus; and (iii) A spirally coiled structure, resembling the shell of the snail, the *cochlea.* Arising from the utriculus is an endolymphatic duct.

The semi-circular canals are disposed of in 3 different planes at right angles to each other. One is vertical and anterior the second is also vertical but posterior, and the third is horizontal. Each canal is swollen at one end to form an ampulla. The canals open at either end into the utriculus.

The cochlea is the essential organ of hearing and contains *organ of Corti*, which consists of five rows of elongated ciliated auditory receptor cells or *hair cells,* provided with nerve endings at their bases. Towards their free ends in the endolymph the cilia are in contact with a thin delicate membrane, the *tectorial membrane.* Its one end is fixed, while the other end is free to move with the movement of the fluid in which it is situated.

Working of the ear. The sound waves, which are collected by the ear pinna and conveyed to the tympanum through the auditory canal, set the tympanum into vibrations. These vibrations are conveyed by the chain of ear ossicles to the internal ear. The perilymph surrounding the membranous labyrinth is set into wave-like motions which, in turn, set the endolymph into vibrations. These vibrations cause the hair-cells of the organ of Corti to rub against the tectorial membrane. The hair-cells, thus stimulated, initiate an impulse which is carried to the brain by the auditory nerves, where the sensation of sound is realised.

The utriculus and its semi-circular canals are not auditory in function. They are responsible for the maintenance of balance and the equilibrium of the body.

SUMMARY

1. A sense organ is specialised to receive one or the other kind of stimuli from environment.
2. The different stimuli are (a) Skin (b) Tongue (c) Nose (d) Eye and (e) Ear.
3. Skin is sensitive to touch, pressure, pain and difference in temperature.
4. The dermal papillae beneath the epidermis contain sensory cells which are sensitive to touch, pressure etc.
5. The tongue is responsible for the realisation of taste.
6. The taste buds are situated on the tongue.
7. Taste buds are groups of sensory cells arranged capsule with a small aperture on the upper pole.
8. The upper free ends of sensory cells are provided with sensitive hair like processes and basal ends are connected to nerve endings.
9. Nose is the organ of smell.
10. The nasal cavity is lined with mucus membranes which contain olfactory receptors.
11. The olfactory receptors have olfactory hairs at the distal end and olfactory nerve fibres at the basal end.
12. The impulse is carried to the central nervous system through the olfactory nerves.
13. Eyes are the organs of sight.
14. The eyes are lodged in bony cavity called orbit.
15. The eyelids and eyelashes protect the eyes from dust and bright light.
16. Eye ball consists of three layers viz. (a) sclerotic (b) choroid and (c) retina.
17. Sclerotic layer is outermost. It is opaque on all sides except in front where it forms a transparent portion called cornea.
18. Choroid, the middle layer, continues in front beneath the cornea where it leaves a small aperture called pupil.
19. The iris regulates amount of light entering the eye.
20. The crystalline lens divides the cavity of the eye ball into anterior aqueous chamber and posterior vitreous humor.

21. Retina is light sensitive layer.
22. Ear, the organ of hearing is divided into three parts namely, (a) External ear (b) Middle ear and (c) Internal ear.
23. The external ear includes the pinna and the auditory canal.
24. The middle ear consists of a bony cavity, namely, the tympanic cavity and the eustachian tube which extends from nasopharynx to the tympanic-cavity.
25. The tympanic cavity contains 3 small movable bones namely (a) malleus (b) incus and (c) Stapes.
26. Internal ear consists of membranous labyrinth surrounded by bony labyrinth.
27. The bony labyrinth is filled with perilymph and the membranous labyrinth with endolymph.
28. The membranous labyrinth contains
    - (i) Utriculus and Sacculus.
    - (ii) Three semi-circular canals and
    - (iii) Spirally coiled cochlea.

BIOLOGICAL WORDS

Stimulus
Pypilla
Taste bud
Olfactory receptor
Lacrymal glands
Sclera
Choroid
Retina
Aqueous chamber
Vitreous humour

Tympanic membrane
Eustachian tube
Malleus
Incus
Stapes
Membranous labyrinth
Otoliths
Utriculus
Sacculus
Cochlea

QUESTIONS

1. Describe the structure of eye or ear of man.
2. Write short notes on:—
   (1) Taste bud (2) Skin of Man, (3) Membranous labyrinth.
3. Give one important function of the following:
   (1) Tongue, (2) Skin, (3) Semicircular canals.

Habitats

16

All life is confined to a shallow zone at the surface of the earth where soil, water and air meet and intermingle to some extent. Therefore, any organism must live in water or air or soil, or in any combination of the three. The habitat is defined as a place inhabited by organisms. It has its own particular kind of environment.

There are three major habitats :

(1) Water, (Aquatic); (2) Land (Terrestrial); and (3) Air (Aerial).

As these three media differ greatly in their physical properties, they present their own special problems to the organisms that inhabit them. Accordingly, animals show particular adaptations so as to suit the environment in which they live. These adaptations are in response to diverse requirements, such as mechanical support, locomotion, respiration, reproduction, temperature changes, etc., which are so much unlike in the three different media.

1. Water or Aquatic Habitat

It is mainly of two kinds : (a) Marine and (b) Fresh water.

(a) **Marine habitat.** Since the time when life originated in the seas, it has continued to support most diverse communities of animals. It is characterised by high salinity, with little or no variations, the range of salinity being 30 to 37 parts of salt per thousand. There are fewer fluctuations in temperature.

The marine habitat is divided into (Fig. 176.) (1) Littoral; (2) Pelagic; and (3) Abyssal regions.

(1) **The Littoral Zone** includes (i) Intertidal zone (between high and low tides), and (ii) Shallow sea.

Some marine organisms living in the intertidal zone are subjected to alternate drying and wetting and constant temperature changes. This zone is at places rocky, sand and muddy.

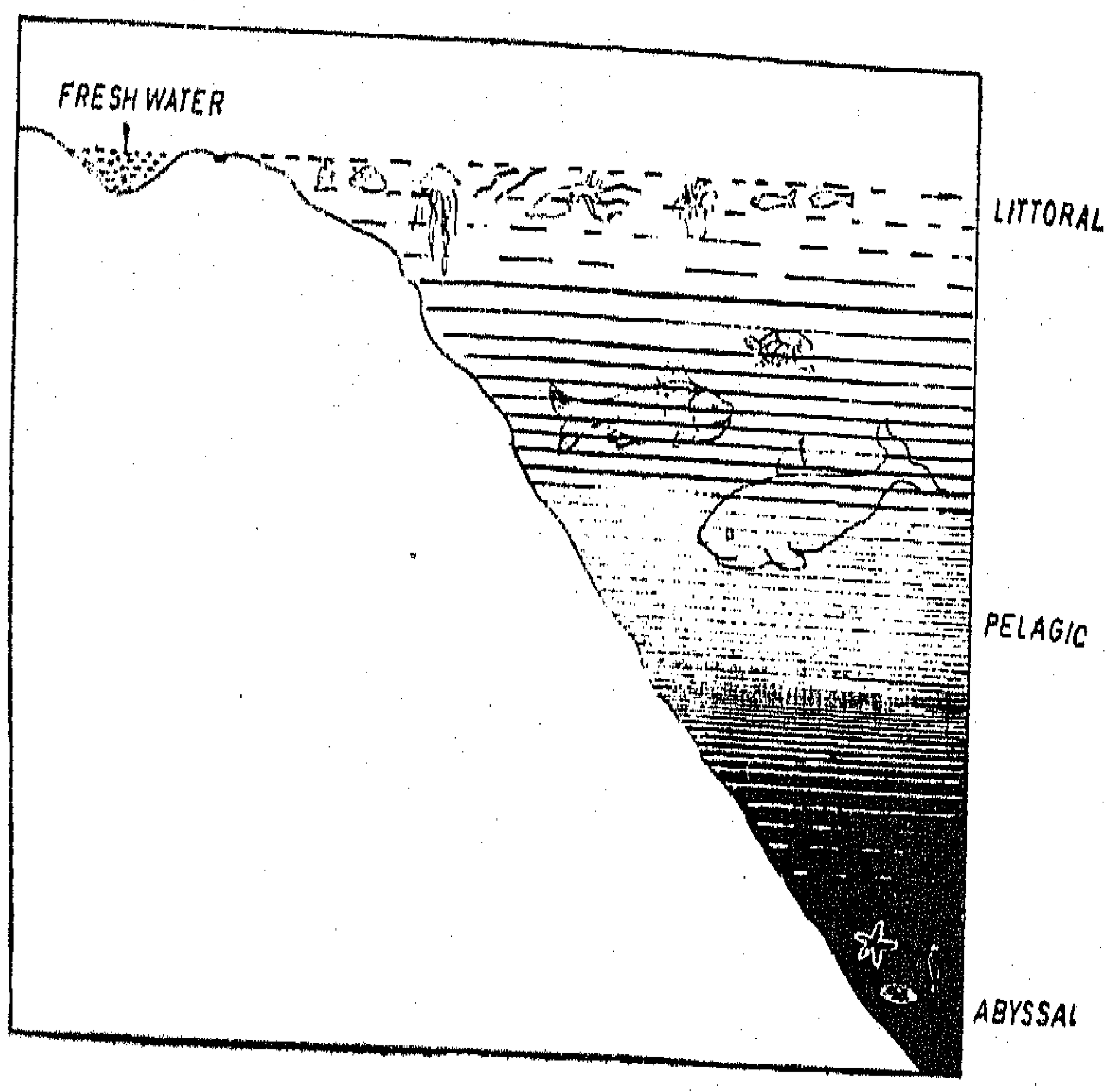


Fig. 176. *Marine Habitat*

Organisms below the low-tide mark, *i.e.*, shallow sea, are subject to fewer fluctuations of the environment.

The animals of the littoral zone exhibit a great variety of adaptations for adhesion and burrowing. The sedentary animals protect themselves by being enclosed in a hard exoskeleton. This zone is thickly populated, and it includes some coelenterates, sponges, planarians, annelids, barnacles, molluscs and echinoderms.

(2) **The Pelagic Zone** includes columns of water upto the depth of which the light can penetrate. Except for the surface waters, the enviornment is relatively constant and stable. It has no substratum.

The pelagic animals found in the open seas are divided into (i) Plankton and (ii) Nekton. The planktonic animals float or drift passively with the help of currents, waves and winds. The examples of the planktonic forms are protozoans, jellyfishes, minute crustaceans and larval stages of many marine animals. The nekton includes the actively swimming organisms, such as sepia and loligo, most of the fishes, turtles, sea-snakes, whales and seals.

(3) The **Abyssal Zone** comprises the deeper waters, where light does not penetrate; hence it has perpetual darkness. The temperature of the water is very low, and the pressure is enormous. The animals at such depths are of unusual size. They are dorsoventrally flattened, and most of them are provided with luminescent organs. They are brilliantly coloured. Some of them are totally blind, while some others have telescopic eyes. The bottom dwellers of this region constitute *Benthos*. Among the deep-sea animals, sponges, coelenterates, arthropods, molluscs are found in abundance.

(b) **Fresh water** is characterised by low salinity, and greater fluctuations in temperature. It also differs from the ocean, in that it undergoes periodic drying up and stagnation. This habitat, therefore, supports a limited fauna Fresh-water habitat can be divided into (1) Stagnant waters (lakes and ponds) and (2) Flowing waters (rivers and streams).

Animals in stagnant waters are less active and include forms like hydra, planarians, mosquito larvae, some crustaceans (Cyclops and Daphnia), Pila and frogs.

Since the water in the rivers and streams moves rapidly, the animals therein must be either active swimmers or must be so adapted as to remain attached by means of hooks and suckers to aquatic weeds or to any other substratum. The flowing-water forms include animals like crayfishes, bivalves, snails, fishes, newts, otters, beavers, etc.

2. Land or Terrestrial Habitat

This habitat shows the greatest variations in temperature, humidity and other climatic factors. Due to these fluctuating conditions, the terrestrial forms exhibit a wide range of adaptations.

Terrestrial habitat can be divided into (a) Subterranean (*i.e.*, underground); (b) Surface; and (c) Arboreal.

(a) The subterranean habitat is the least subjected to variations in climate. The animals included here are the cave animals and the burrowing or *fussorial* animals. They are either blind or have much reduced eyes. In some fussorial animals the limbs

or appendages are altogether absent, *e. g.*, earthworms and snakes. In some other fussorial animals, the limbs are provided with powerful claws for digging the burrows; *e. g.*, moles and shrews. Other animals included here are the rodents such as rats, mice, rabbits and squirrels.

(b) **Surface.** This habitat suffers from great fluctuations in temperature and humidity. These fluctuations are both diurnal and seasonal. Depending on the nature of the vegetation, this habitat is grouped into (i) Desert; (ii) Grassland; (iii) Shrub zone; and (iv) Forest.

(i) **Desert.** It is subjected to the maximum climatic variations. The soil is extremely dry and the need for the conservation of water is acute. The camel is the most well-known example of this zone. Also included are rodents, ostriches and lizards.

(ii) **Grassland.** It is characterised by an abundance of food and low humidity. Therefore, it supports a variety of such grazing animals as the bison, buffalo, sheep, prairie dog, rabbit and hare. The birds, like sparrows and larks, snakes and a large number of insects frequent this zone.

(iii) **Shrub zone.** This zone is inhabited by small birds, lizards, a few snakes and many insects.

(iv) **Forest.** The important features of this habitat are: (1) Hight humidity and (2) Sheltering of the animals against wind and heat of the sun. It also provides an abundance of food in the form of roots, leaves, stems and fruits for plant feeders. Predominating over the docile plant-feeders are the predators in the form of birds and mammals. These carnivorous animals include birds of prey, tigers, lions and leopards.

Arboreal. This habitat includes animals which spend most of their time among trees. The limbs and tails of arboreal animals are Prehensile. In some, the digits are opposable, which is an adaptation for grasping. Examples of this habitat are squirrels, monkeys, chameleons, bats, etc.

Air (Aerial) Habitat

It is a very peculiar habitat in that it does not provide mechanical support as the other two media do. This fact introduces new problems for adaptation. Flight is the only method of locomotion in the air for which the body has to be streamlined and light.

Aerial animals are distinctly related to the land, for to the land they must return for resting, feeding and breeding. One of the special adaptations towards this environment in these animals is the possession of an expanded, flattened, air-resistant membrane. In Draco, bats and Galeopithecus, it is the patagium (skin fold); and in birds it is the wing which represents the modified fore-limbs. The wing is made up of a unique structure, the feathers, which are found nowhere else outside Aves. The birds, being best adapted for the aerial habitat, possess many more adaptations, such as a stream-lined body, hollow pneumatic bones, presence of air sacs, loss of teeth etc.

SUMMARY

1. The three major habitats are (i) Water (ii) Land and (iii) Air.
2. The aquatic habitat may be (i) marine and (ii) fresh water. The first one is sub-divided into (a) Littoral, (b) Pelagic and (c) abyssal regions, while the latter is divided into stagnant water and flowing water.
3. Terrestrial habitat could be (i) Subterranean (ii) Surface or (iii) Arboreal.
4. Flight is the only method of locomotion in air for which the body is streamlined and light.

BIOLOGICAL WORDS

Littoral
Pelagic
Abyssal
Plankton
Nekton
Fussorial
Benthos
Arborial

QUESTIONS

1. Describe the fauna of sea.
2. What are the adaptations of Desert forest and aerial Animals.

Locomotion 17

Locomotion is one of the characteristics by which animals can be distinguished from sedentary plants. It is a rule in animals. However, some lower animals like sponges, a few coelenterates and some annelids are exceptional in leading a sedentary life.

Locomotion is the capacity of an organism to move from place to place. The main purpose of locomotion seems to be concerned with the survival either of the individual or of the race. It is mostly directed at finding food, mates and dwellings, and avoiding predators and other hazards. They can be classified as follows: (1) Locomotion in search of food; (2) Locomotion in search of shelter (escape from enemies); and (3) Locomotion in search of a mate for breeding.

Locomotion is achieved in different animals in a variety of ways. Mainly, there are three mechanisms in locomotion, *viz.*, amoeboid, ciliary and muscular.

Locomotion in Amoeba

The amoeba is an acellular animal which is found at the bottom of stagnant fresh-water pools. It has no definite shape, for it continuously changes it by the formation of *pseudopodia*, which are the organelles of locomotion.

A pseudopodium is a blunt, finger-like temporary projection capable of being protruded from any region of the body. In the direction of locomotion, the pseudopodium is thrust out, slightly raised above the surface of the substratum. The free end of this pseudopodium now gains attachment with the substratum. Simultaneously, the remaining part of the body is released and pulled forward, bringing about displacement in the required direction. In other words, progression takes place. In this locomotion, a number of pseudopodia may be thrust out in the direction of the movement.

The physico-chemical aspect of the formation of the pseudopodia can be well understood from the animal structure.

The amoeba is bounded by an elastic plasma membrane. The cytoplasm consists of an outer clear ectoplasm and the inner mass of endoplasm. This endoplasm is further distinguished into an outer rigid layer of protoplasm, the *plasmagel*, and an inner core of granular fluid protoplasm, the *plasmasol*.

At the point of formation of a pseudopodium, the firm plasmagel becomes converted into a "sol" condition, whereby the rest of the cytoplasm flows forwards, stretching the ectoplasm and plasma membrane. The stretching of the elastic plasma-membrane results in the formation of a pseudopodium. The indefinite growth of the pseudopodium is checked by the gelation of the plasmasol at the free pseudopodial end. Thus, the amoeboid movement is fundamentally a process of sol-gel formation and vice versa.

The *ciliary* mode of locomotion is found in some protozoans like the paramecium. The cilia are protoplasmic threads given out from the surface of the body, and internally connected to a neuromotor system of fibrils.

Locomotion in Hydra

Hydra spends most of its time attached to the substratum. Occasionally, it performs locomotion by various methods. (Figs. 177 & 178).

(1) **Looping**. In this mode of locomotion, the free end of the animal is bent till it reaches the substratum, where the tentacles get hold of the substratum firmly. Next, the basal disc, by which it is normally attached, is pulled forward, after which the tentacles release their hold, and the animal straightens up. Thus, it achieves progression.

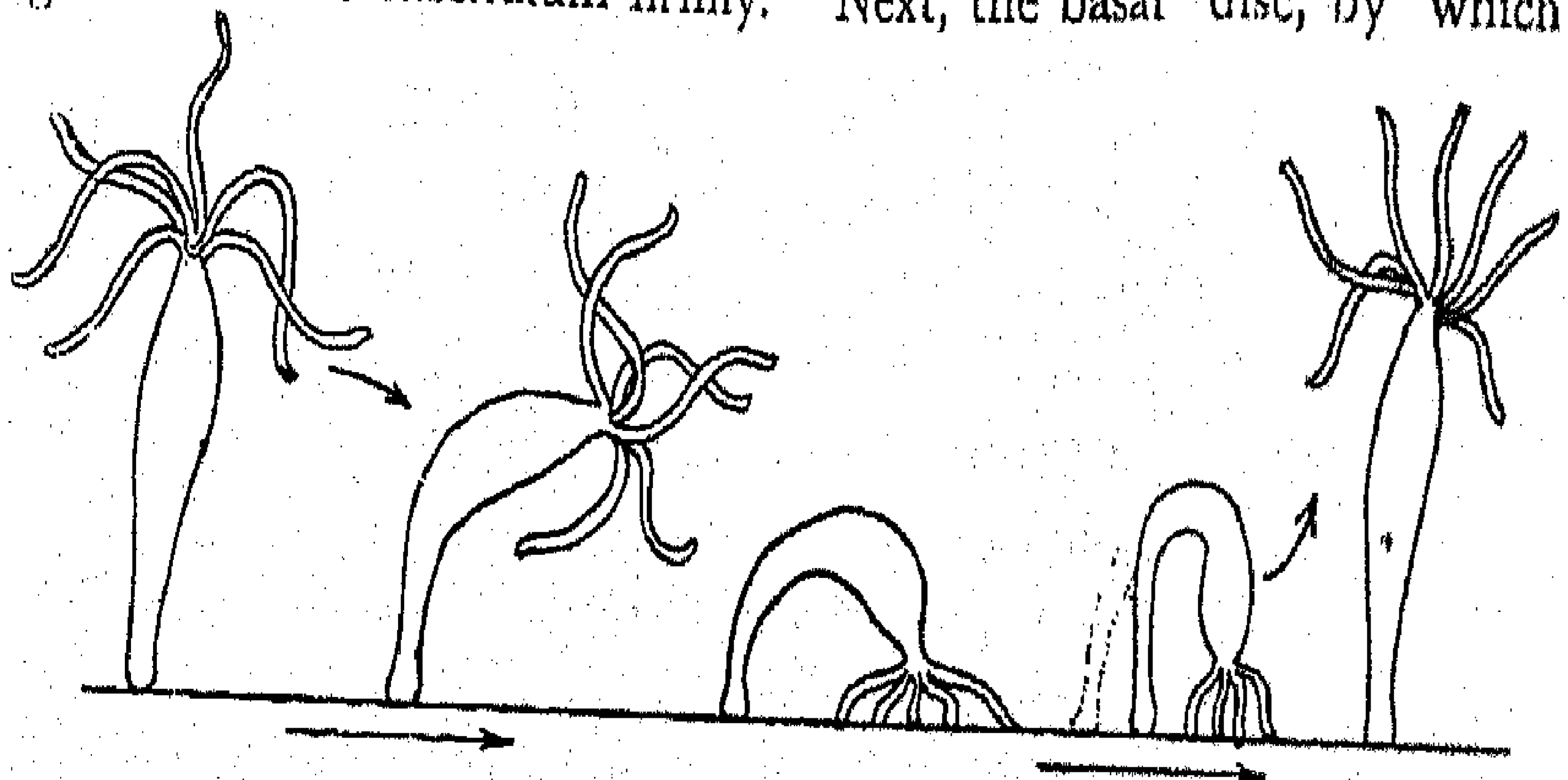


Fig. 177. *Hydra : Looping movement*

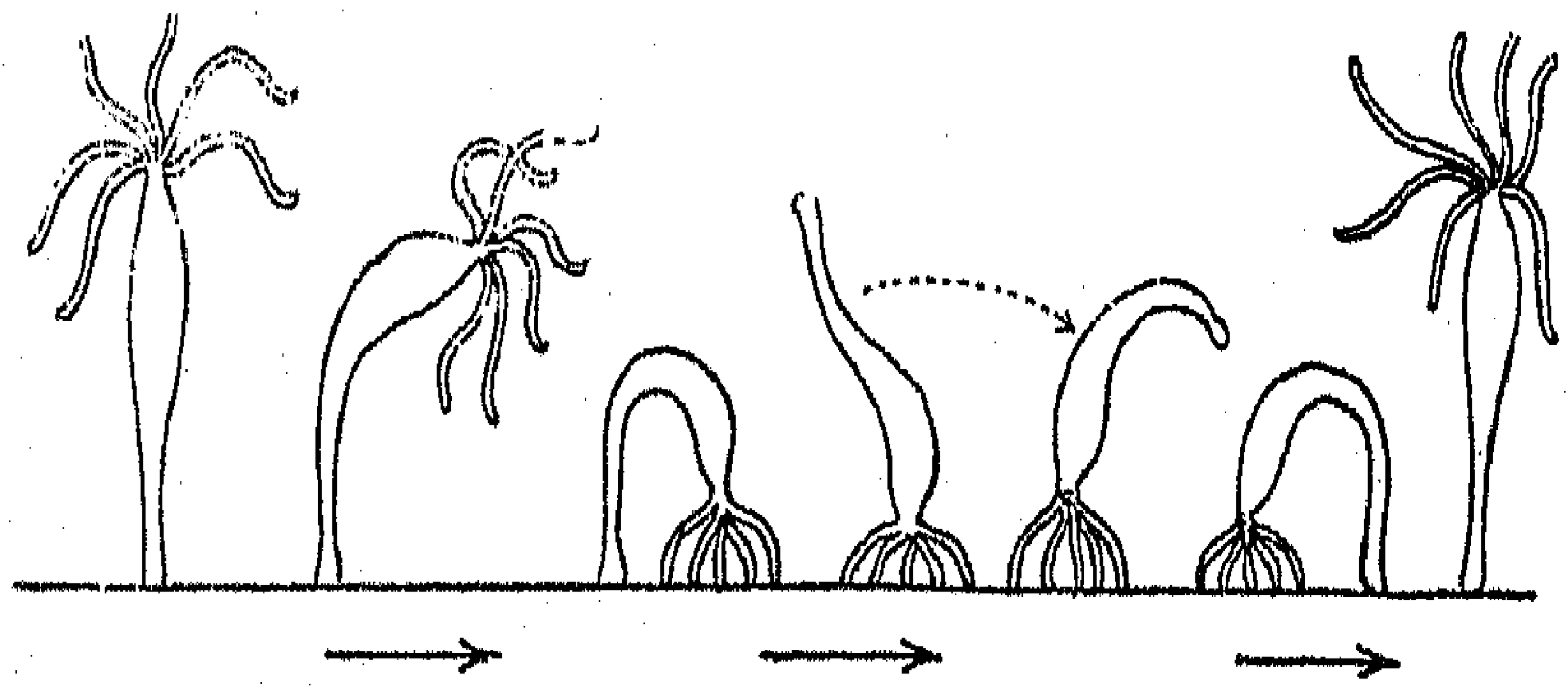


Fig. 178. *Hydra : Somersaulting movement*

(2) **Somersault.** Here, as in the looping movement, the basal disc is released after the tentacles have taken hold of the substratum and the hind end of the body is lifted up and swung in the opposite direction so that the basal disc gets fixed to the substratum. The tentacles are released, and the animal assumes the normal upright posture. This is a faster mode of movement than the looping mode.

(3) **Gliding**. Here, the animal moves forward very slowly by the gliding motion of its basal disc along the surface. This movement is performed by reason of the function of the amoeboid ectodermal cells of the basal disc.

(4) **Floating.** The animal detaches completely from the substratum and floats and drifts at the surface with the help of a gas bubble, which is enclosed by the mucous droplets secreted by the basal disc.

The latter two methods are very slow and less frequent.

Locomotion Earthworm

The earthworm can creep in either direction. The locomotor organs are the setae, which are microscopic, chitinous S-shaped structures, secreted by the setigerous sacs in the body-wall. They can be protruded and retracted with the help of protractor and retractor muscles. The body cavity is the coelom, filled with an incompressible coelomic fluid. There are longitudinal and circular muscles in the body-wall. The length of the body is decreased and the diameter increased by the contraction of longitudinal muscles, while the diameter is reduced and the length increased by the contraction of the circular muscles.

During locomotion, the setae at the moving end are protruded, and they take a firm grip of the soil. This is followed by the contraction of the longitudinal muscles, which results in pulling of the other end of the body forward. Now the protruded setae are retracted and the setae at the other end are protruded. By the contraction of the circular muscles, the diameter is reduced, bringing the pressure to bear upon the incompressible coelomic fluid. This fluid is pushed forwards, pushing the body also forward.

The locomotion of the earthworm, therefore, consists of alternate pulls and pushes, during which the setae are used as fulcra.

Locomotion in Fish

The fish is an aquatic vertebrate, which swims in the water. It is as perfectly adapted for aquatic locomotion as the bird for the aerial one.

The body is streamlined so as to minimise the friction through the water. It is tapering at both the ends. The locomotor organs are the fins. The fin is an expanded flattened skin, supported by hard fin-rays. There are two kinds of fins, (a) median fins and (b) lateral fins. The median fins are single and unpaired, while the lateral fins are paired. They are in two pairs. The front pair of fins is the pectoral fins, situated at the junction of the head with the trunk. The hind pair of fins, the pelvics, is situated at the junction of the trunk with the tail. They are respectively attached to the pectoral and the pelvic girdles. The median single fins are dorsal, caudal, ventral or anal.

Another organ, which helps the bony fish in swimming, is the air bladder, which is absent in cartilaginous fishes. The air bladder develops as a gas-filled outgrowth from the oesophagus and acts as a hydro-static organ, enabling the fish to change the depth.

Some fishes are capable of 'flying' through the air. In the flying fish (Exocetus), the pectoral fins are greatly enlarged to form large planes, which are used for gliding.

Wall lizard. This reptile is capable of climbing up steep plane surfaces. For this special habit, the fingers and toes are suitably modified. Each digit bears an adhesive disc or pad at the tip. (Fig. 179). This pad is used as a sucker (vacuum cup), which enables the animal to stick to the steep surface.

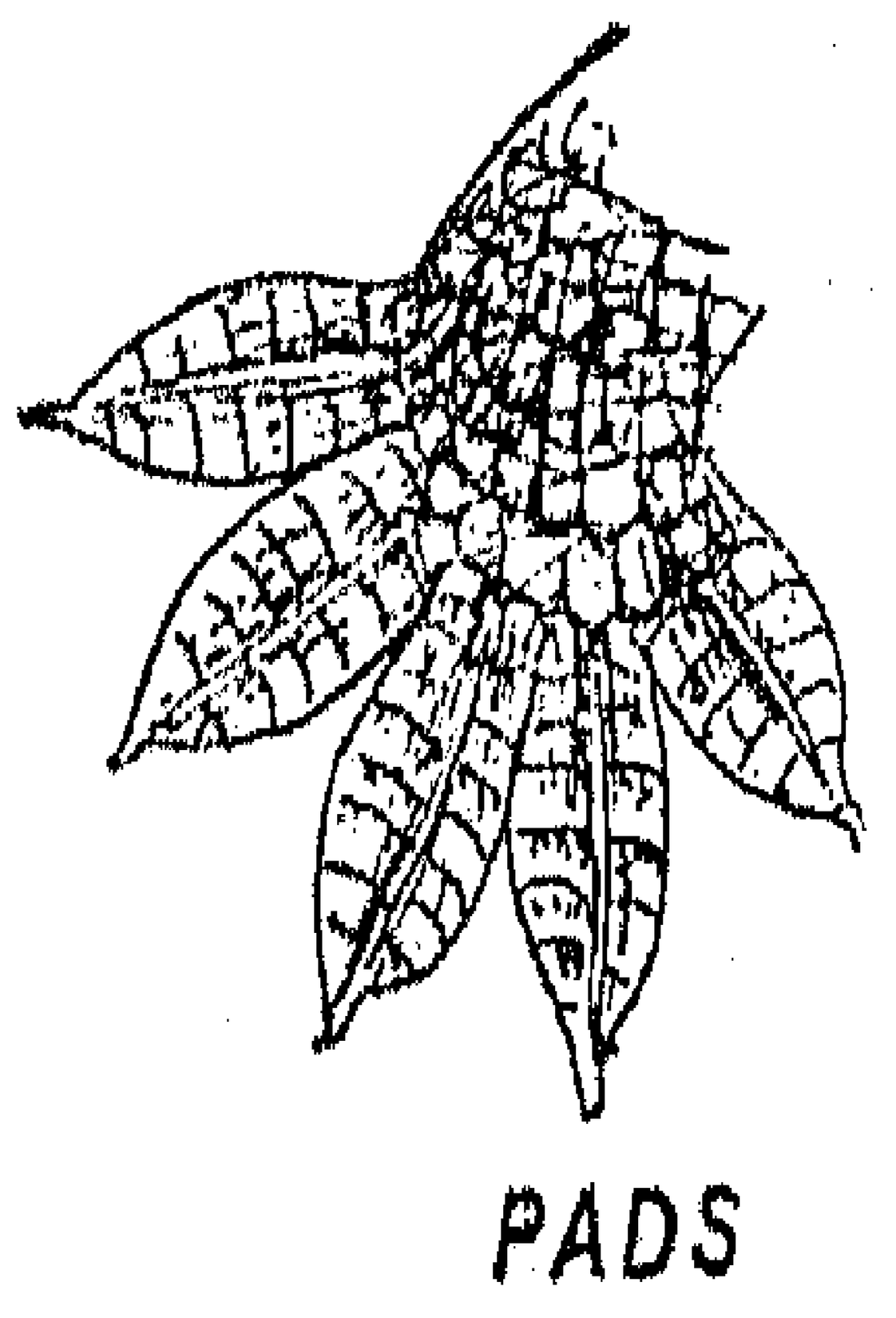


Fig. 179. *Wall-lizard pads*

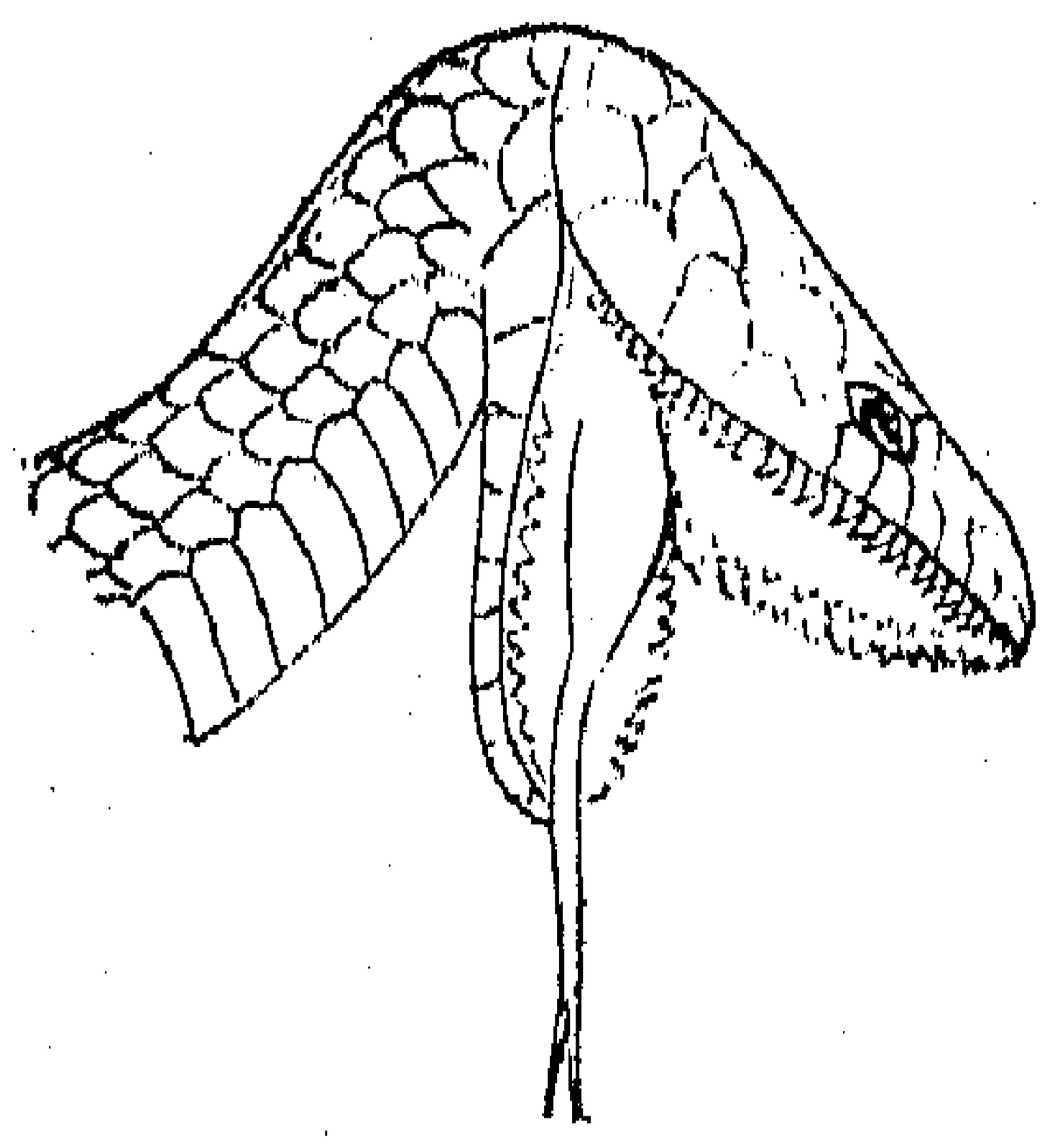


Fig. 180. *Snake: Belly plates*

Snakes. They are fussorial reptiles which creep along the soil. They have all lost their limbs; hence the locomotion is performed with the specially modified belly-scales. (Fig. 180). These scales can be alternately raised (erected) and lowered. During locomotion, they are used as fulcra which, by taking a firm grip on the soil, allow the body to be pulled. For such a kind of serpentine locomotion, the body is required to be extremely flexible. The deeply concavo-convex vertebrae confer this flexibility on the body.

Birds. They are the masters of air. They are the only vertebrates which can truly fly. They are marvellously adapted for the difficult task of flight. The adaptations include one innovation, the feather (Fig. 182), which is the monopoly of birds. Each feather is made up of a cylindrical quill and a flattened vane. In the centre of the vane, there is a rod-like rachis, to which are attached two rows of barbs. Each barb (in the manner of rachis) is, in turn, provided with two rows of smaller, thread-like barbules. The barbules have an interlocking system which holds the vane intact so as to form an air-resistant membrane.

The wings (Fig. 181) are flapped by a powerful flight musculature, which is attached to the sternum. Hence the sternum, instead of remaining a narrow bar-like structure, becomes excessively flattened so as to increase the surface for the attachment of flight muscles The sternum also carries a vertical keel for the same purpose.

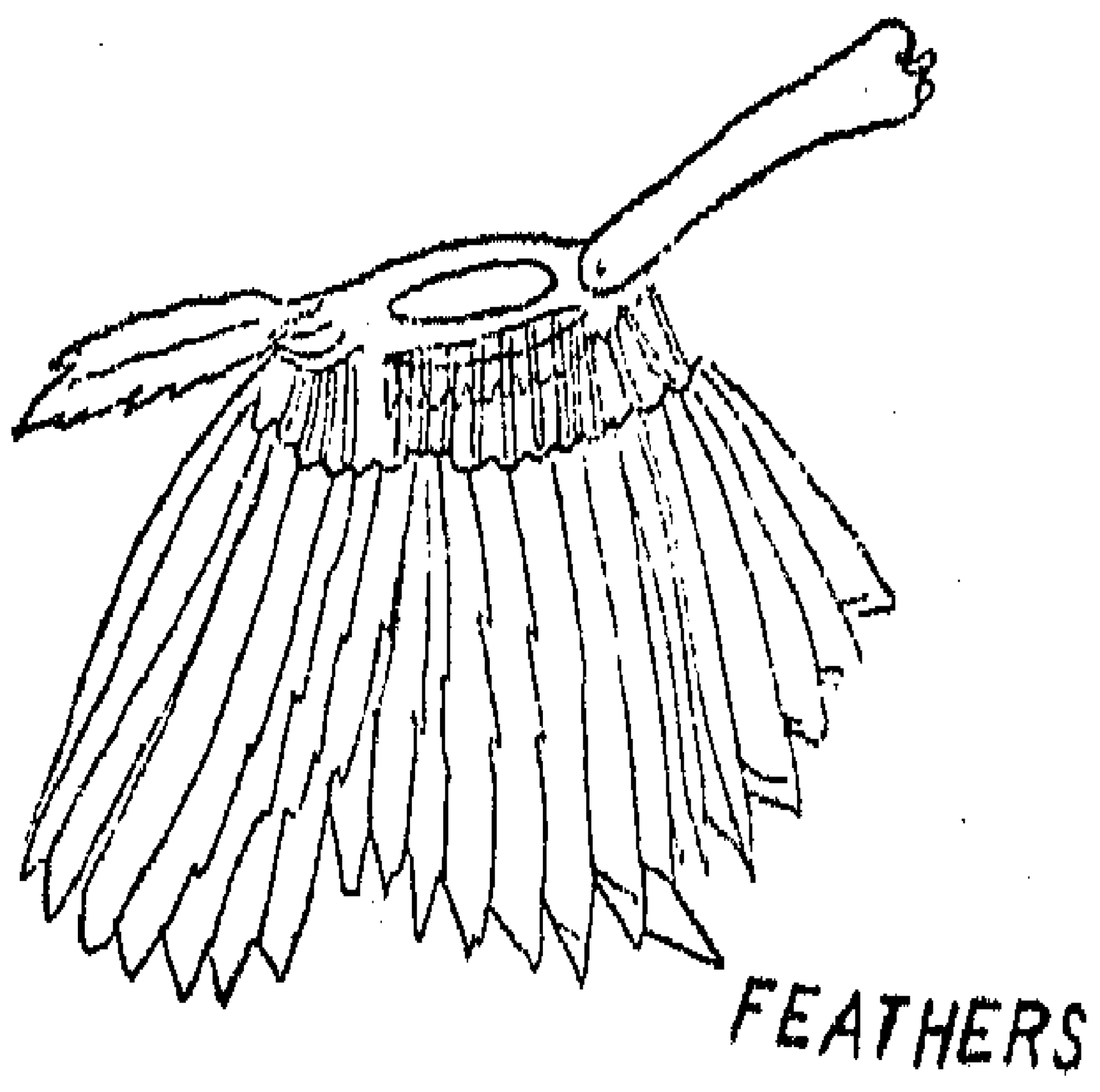


Fig. 181. *Bird : Wing*

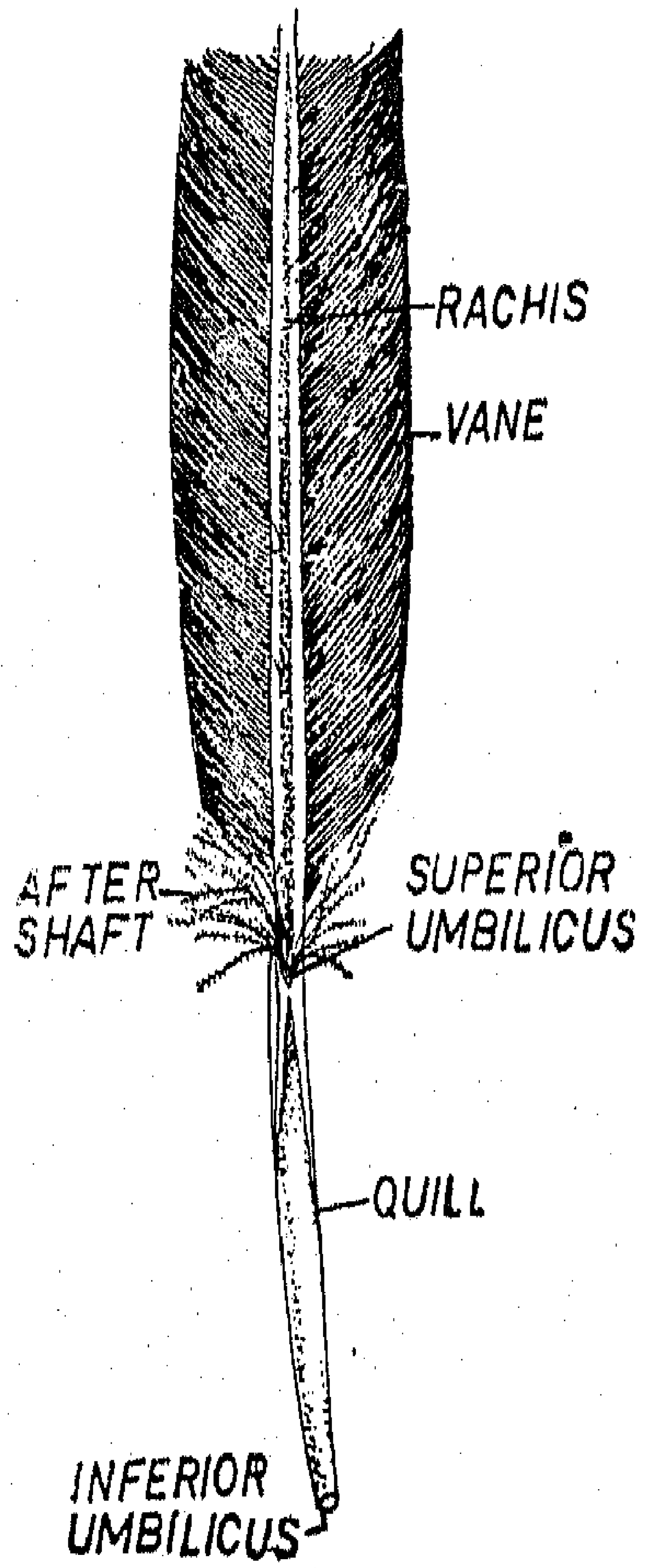


Fig. 182. *Feather*

Air-sacs, which are filled with warm air, help the bird in redusing specific gravity, and give-it buoyancy.

In flightless birds (Ostrich and Emu), the wing musculature and sternum are poorly developed. The keel is absent. These birds, have therefore taken to running. With the help of their long legs and strong hoof-like toes, they can run very fast. (Fig. 183).

Some birds have adapted another method of locomotion, namely, wading through water. Such birds (Cranes and Storks) are characterised by their long-leggedness. This long-leggedness is accompanied by long necks and long bills.

Horse. The present horse is one of the swiftest and most graceful runners. The locomotion of the horse is the last word in perfection. For the swift gait, the limbs are accordingly modified. They are lengthened by the elongation of the limb bones. A con-

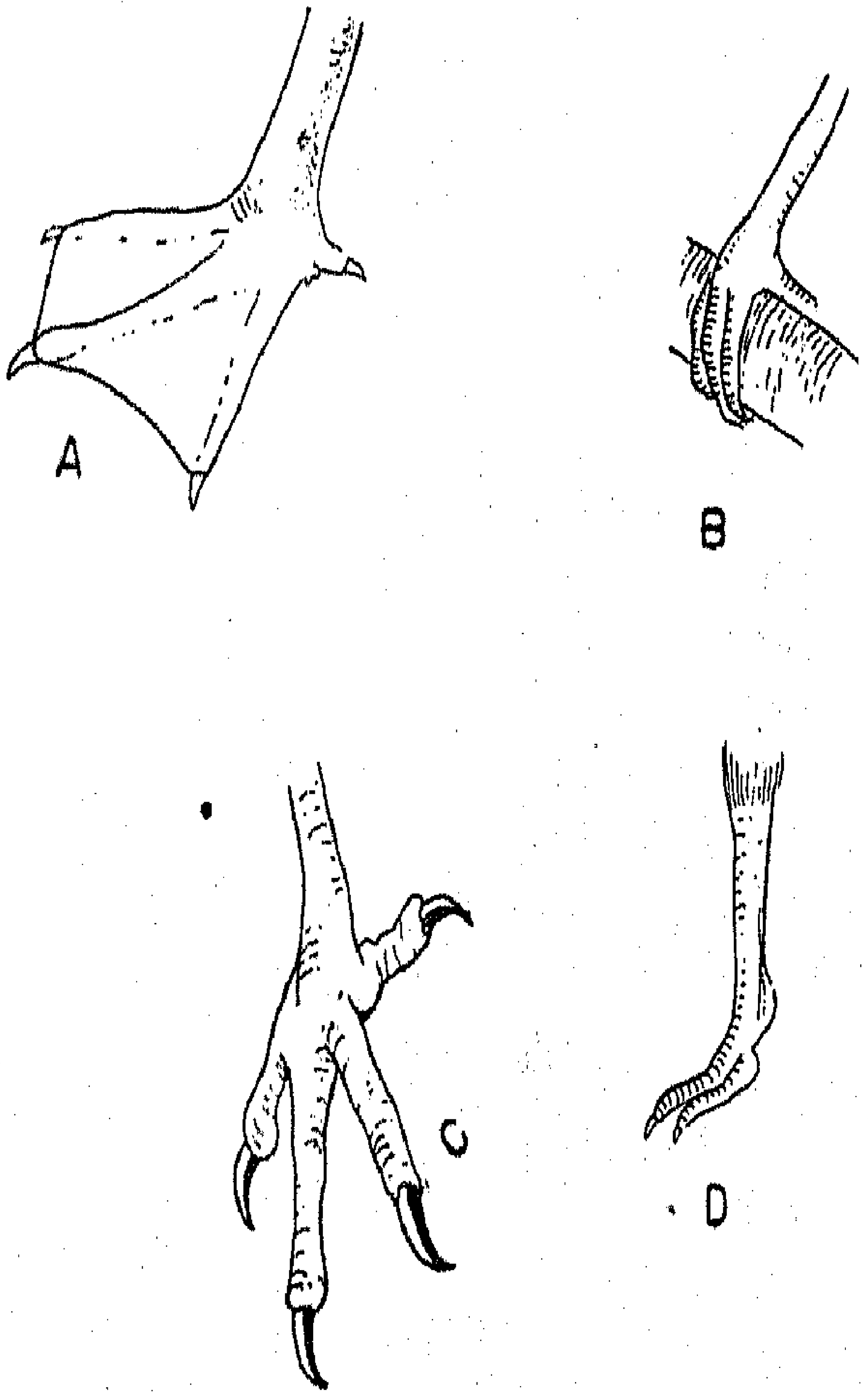


Fig. 183. *Bird, Toes and Feet*

A. Swimming foot of Duck B. Perching foot
C. Raptorial toes D. Running foot of Ostrich

siderable length is added by the raising up of the digits from the ground. In the ancestral horse, the entire foot (sole and toes) rested on the ground, locomotion being known as plantigrade locomotion. Then the sole was raised off, from the ground, producing digitigrade locomotion. In the present horse, locomotion is unguligrade, being performed on the very tips of the nails of digits. In this evolution, the lateral digits, failing to reach the ground, become reduced and ultimately get lost. Thus, the horse has only one digit in each limb, the third one; the second and fourth are represented by vestigial splints, while the first and the fifth are altogether lost. For this unguligrade locomotion, the tips of the toes are enclosed by a characteristic hoof; which is a highly modified nail.

SUMMARY

1. Locomotion is the characteristic feature of animals.
2. Locomotion may be (i) In search of food (ii) In search of shelter or (iii) in search of a mate for breeding.
3. Pseudopodia are the organs of locomotion in amoeba.
4. Hydra performs locomotion by various methods namely (a) Looping, (b) Somersault (c) Gliding and (d) floating.
5. Earthworm creeps with the help of Setae.
6. Fins are the organs of locomotion in fish. The body is streamlined to minimise friction in water.
7. In bony fishes air bladder helps in swimming.
8. Wall lizard has adhesive disc or pad at the top of each digit.
9. Snakes creep along the soil with specially modified belly scales which can be alternately raised and lowered.
10. Birds fly in the air. In the flight, the wings, feathers and the air sacs all help.
11. In horse locomotion is unguligrade.

BIOLOGICAL WORDS

Pseudopodia
Somersault
Seta
barb
Quill
Unguligrade.

QUESTIONS

1. What are the uses of locomotion in animals ?
   Describe locomotion in :—
   (a) Hydra (b) Amoeba (c) Snake (d) Horse
2. Describe locomotion in Bird and Fish.

Parental Care 18

Parental care is the concern for the eggs and the young ones shown by their parents, by either one or both of them. It is at its lowest ebb in the most lowly evolved forms, which show the least care for their eggs and offsprings. In fact, they are divinely oblivious of such things. It gathers complexity as one climbs up the ladder of evolution. The parental care and the production of the offspring are inversely proportional to each other. The lesser the parental care, the larger is the number of eggs (or offspring) produced. Most of the fishes, which do not show parental care, lay a phenomenal number of eggs, that are left to the vagaries of Nature. Hence only a few survive. But in such animals as birds and mammals, who shower care on their offspring, only a few are produced.

This instinct of parental care is present in many animals, invertebrates and vertebrates. We shall confine ourselves to only a few of them.

Mudwasp. After mating with the male, the female insect busies herself with the building of a "nest" or cell out of mud. This dome-shaped cell is built for laying the eggs. But before they are laid, she stores in this cell a few caterpillars and smaller insects, which are paralysed. After the laying of eggs, the cell is sealed and the mother dies. On hatching, the young ones are ready to feed upon the paralysed food, dished out by their dutiful but deceased mother.

Honey-bee. Like ants and termites, they are social insects. They live in colonies, which show a very distinct division of labour in their caste system of a queen, drones (fertile males), workers and soldiers. After mating, the drones die. The only job of the queen is to lay eggs (Fig. 184). Hence, the parents have nothing to do with their products, which are left in the trusted hands of workers. These workers, who are sterile females, are entrusted

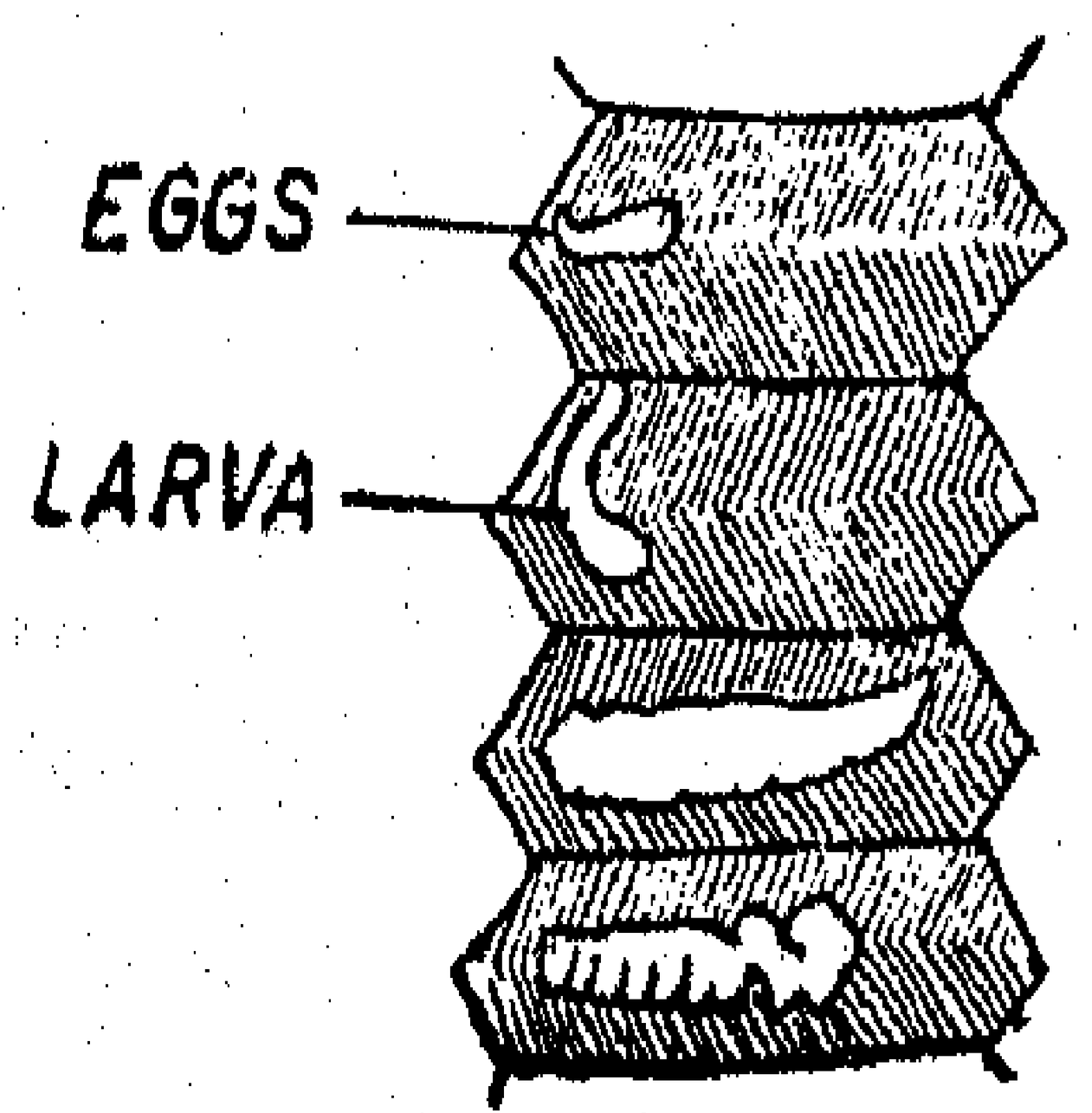


Fig. 184. *Honey comb with larva*

with several duties, such as the building up of the nest, the storing of food in the form of pollen grains and honey, on which the young ones are fed. The soldiers protect the colony.

Oddly enough, in this aristocratic society, there is a communist way of caring for the offspring. Parental care is entrusted to the society and not to the parents.

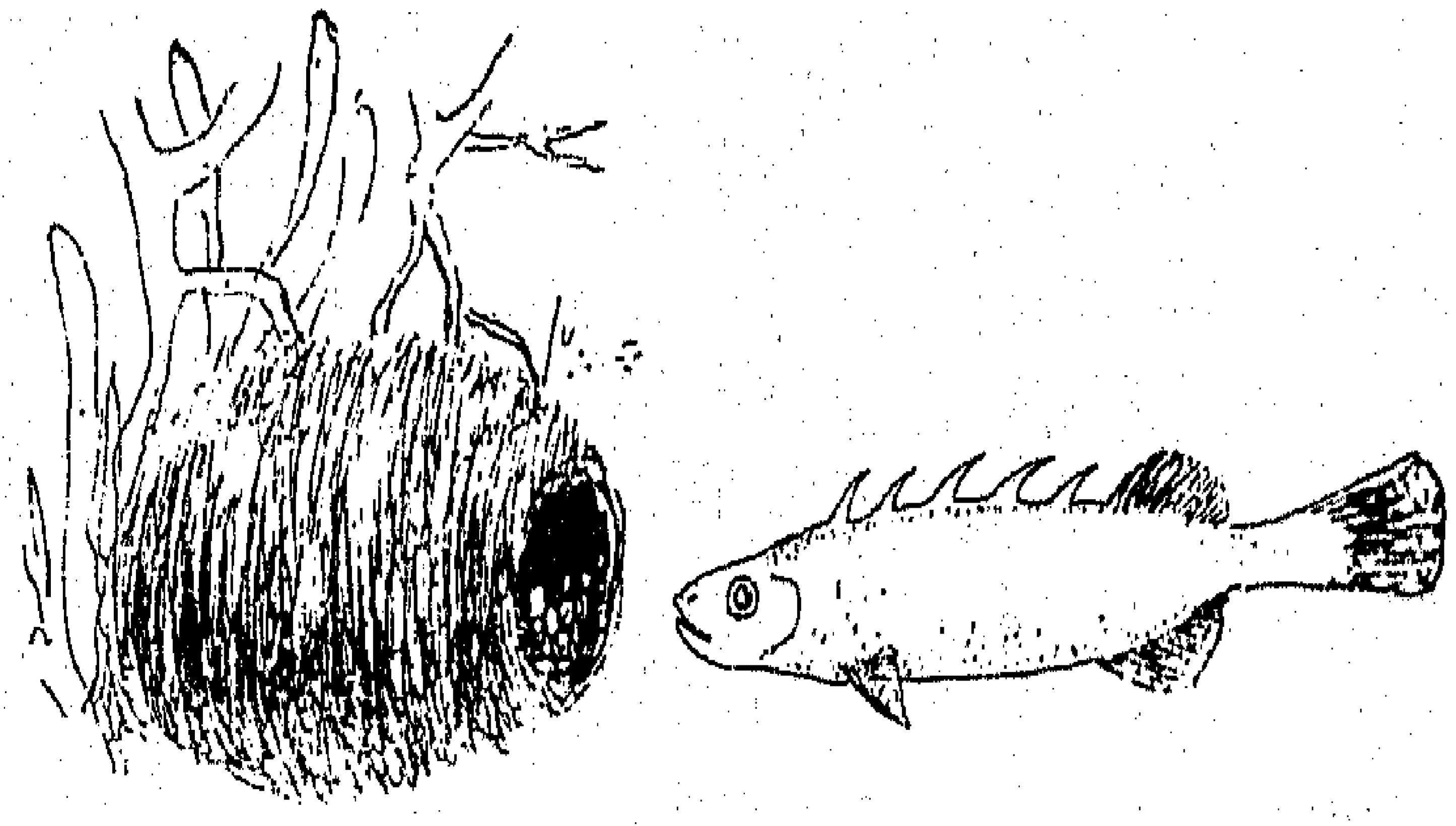


Fig. 185. *Stickleback*

Stickleback. These fishes build a nest of weeds and sticks in the water (Fig. 185.) In this semi-spherical nest, ova are laid by a number of females. Then the polygamous male sheds his sperms over the ova, which are thus fertilised in the nest. The male guards the nest and also aerates and protects the zygotes.

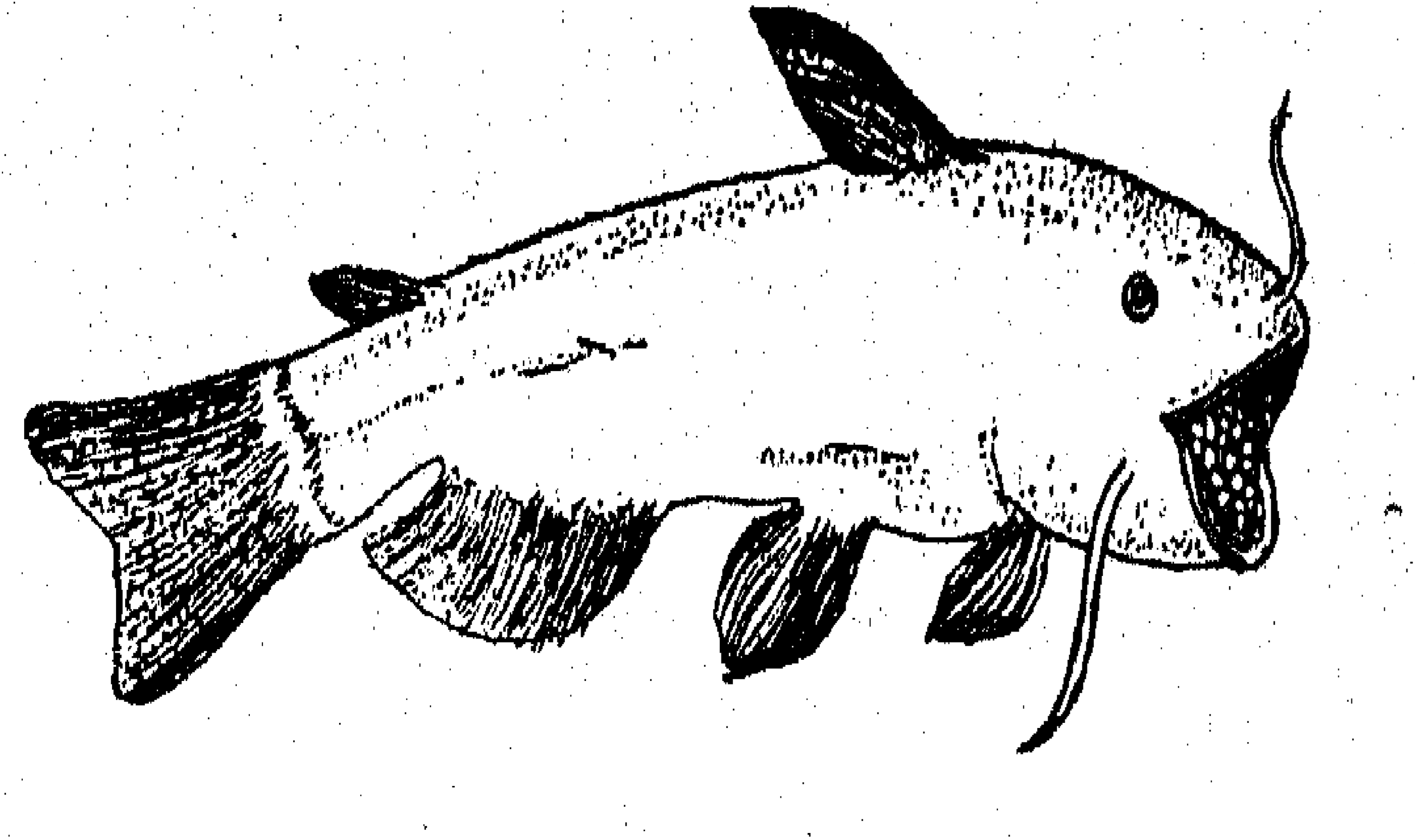


Fig. 186. *Catfish (Male)*

Cat-fish. In this fish, the male carries the fertilised eggs in the mouth till they are hatched (Fig. 186). This is done at great personal inconvenience, since the father cannot at all feed himself while he is carrying the eggs in mouth.

Sea-horse. In this fish also, the chivalrous male takes up the function of affording shelter and protection to the eggs. The male has an abdominal brood-pouch, where the fertilised eggs are safely lodged till they are hatched.

Mid-wife toad. In this amphibian, the male carries the egg-strings fastened to its hind-limbs (Fig. 187). It constantly moistens them in water, where ultimately the tadpoles are set free.

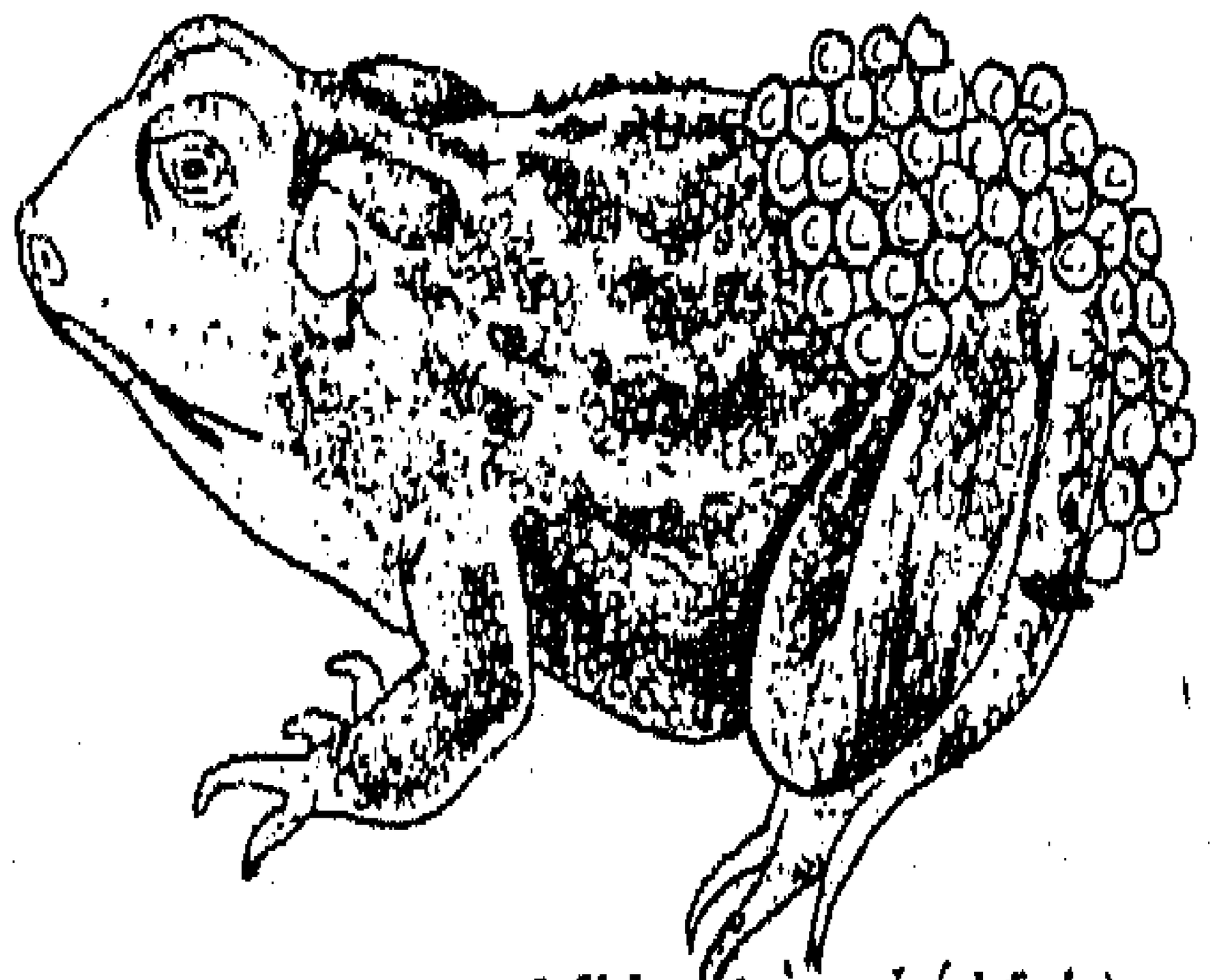


Fig. 187. *Midwife toad (Male)*

Birds. They are well known for their perental care. The bird begins with the building up of the nest, which presents a great

Fig. 188. *Woodpecker*

variety in structure, position, composition and ingenuity. They may be extremely simple, being built up of dried leaves and twigs, as in the nests of crows. In some birds, like the wood-pecker and the owl, the dwelling is hollowed out in the bark of trees (Fig. 188) Some birds are known to weave a nest. The tailor-bird sews a couple of leaves to improvise a nest. The weaver-bird nest is a fine piece of craftsmanship in weaving.

After incubation, when the eggs are sat upon by the mother, the young ones are hatched. These helpless nestlings are fed by their parents, who push the food into the evergaping mouth of the young ones.

Kangaroo. It is a mammal and is, therefore, viviparous, giving birth to young ones, who are weaklings. These young ones are carried by the mother in a special bag-like marsupial pouch (Fig. 189). As in any other mammal, the young ones are suckled by the mother on her own milk.

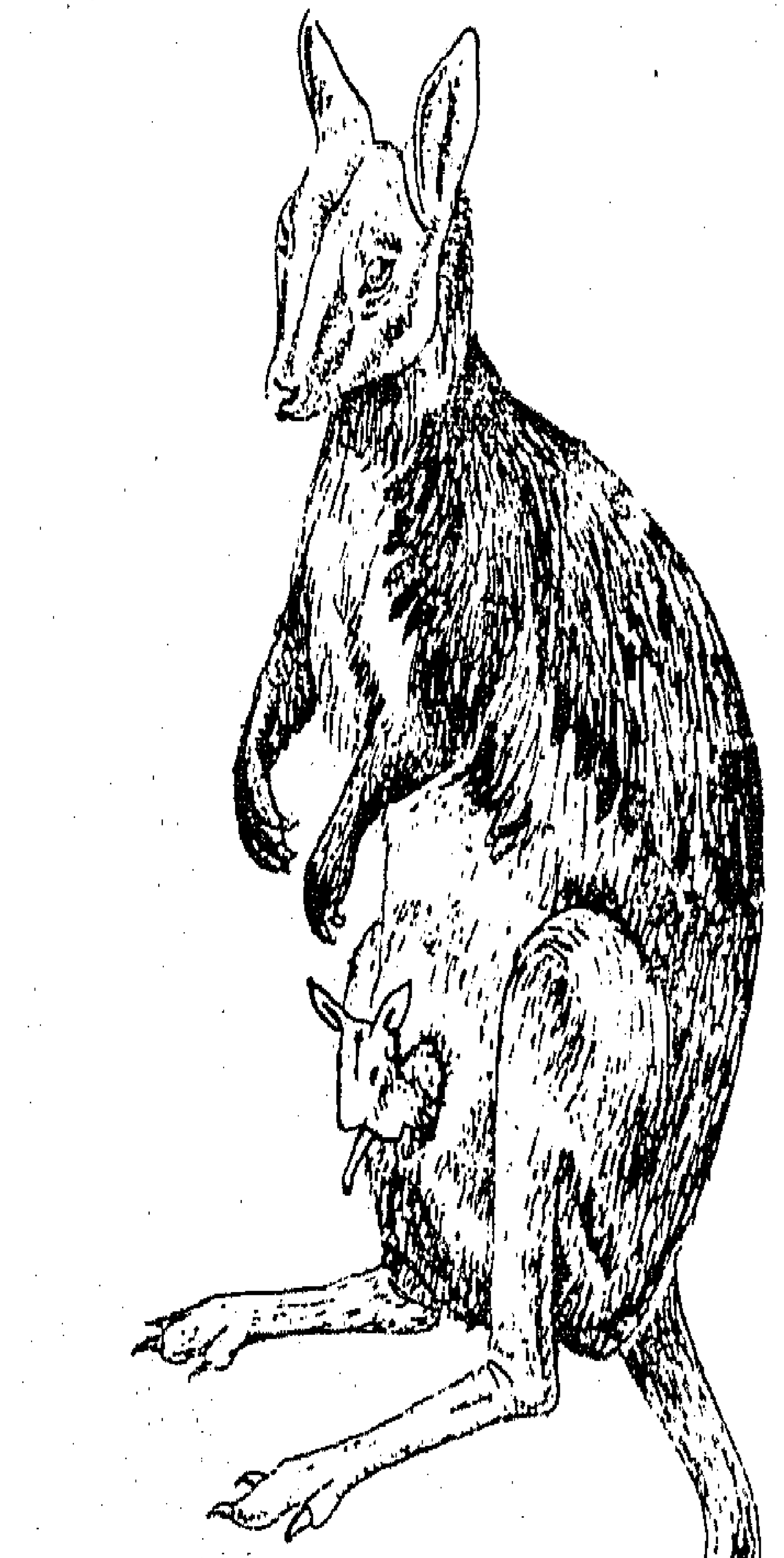


Fig. 189. *Kangaroo*

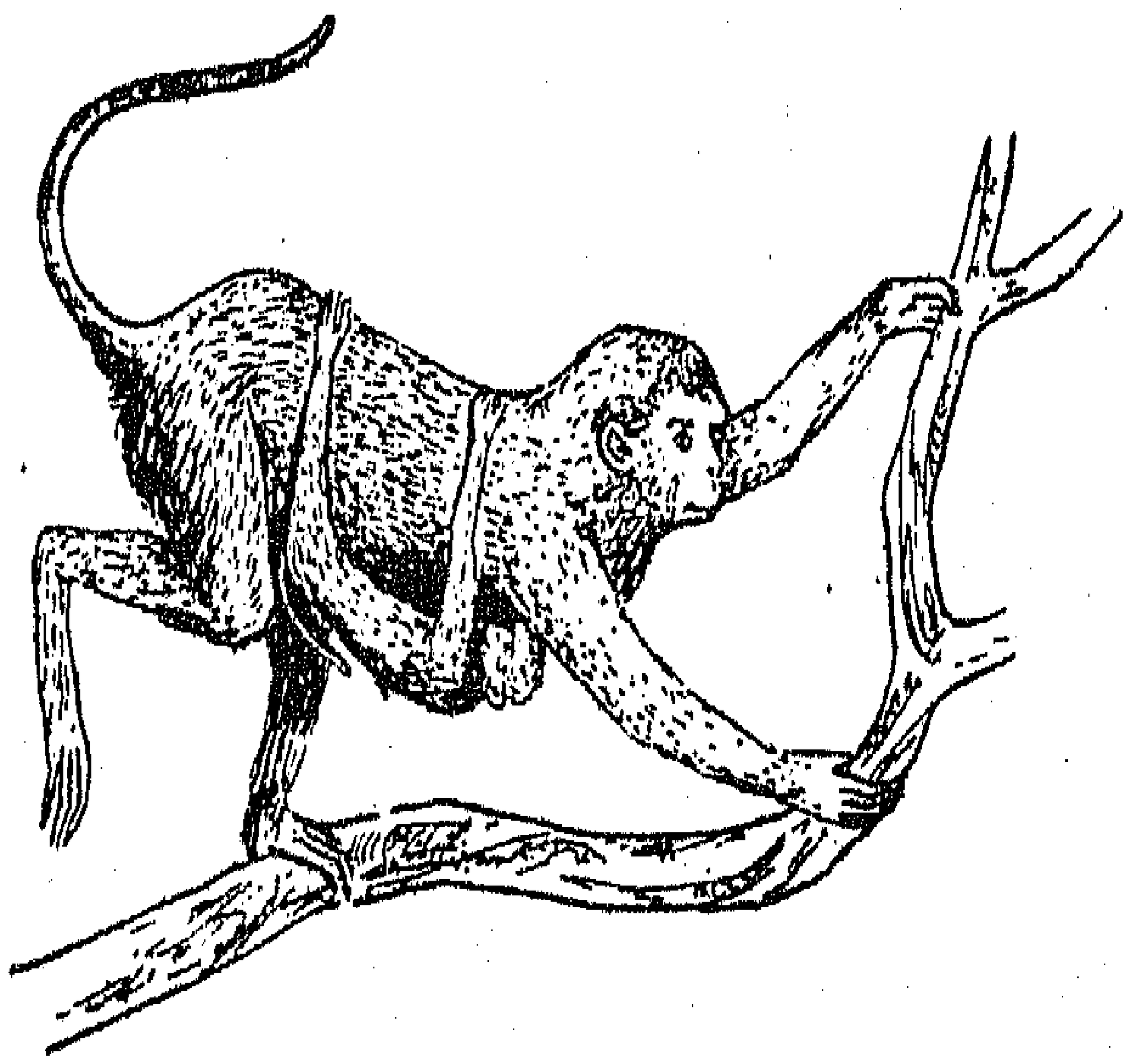


Fig. 190. *Monkey*

Monkey: In monkeys, as in man, only one young one is given birth to at a time. They are properly looked after by their parents, who teach them all the basic lessons of survival (Fig. 190). It is commonly seen that the mother carries its young one wherever it moves, with the young one clinging to its underside.

Parental care culminates in perfection among human beings. The prolonged period of gestation, the helpless condition of the new born infants and the protracted period of infancy have all resulted in the accentuation of the finest sentiments for human progeny.

SUMMARY

1. Parental care is the care taken by the parents of their young ones.
2. This depends on the number of young ones produced.
3. Mudwasp builds a cell of mud which is filled with insects and caterpillers for the young ones born after the eggs hatch. The cell is sealed after the eggs are laid.

4. Honey-bees live in colonies. The queen bee only lays the eggs. The workers build the nest and store the food in the form of pollen grains and honey. Parental care is entrusted to society and not to the parents.
5. Stickle-back builds a nest of weeds and sticks. The females lay eggs in the nest which are fertilized by the male. This nest is guarded by the male.
6. In catfish the male carries the eggs in the mouth till they are hatched.
7. Male Sea-horse has a brood pouch where fertilized eggs are stored till hatched.
8. The male mid-wife toad carries the egg strings fastened to the hind limbs.
9. Birds build nest to lay eggs. The weaver birds and tailor birds are noted for this.
10. Kangaroo has a marsupial pouch in which the prematurely born baby is sukled and further development completed.
11. In monkeys the mother carries the young one every where with the young one clinging to belly.

BIOLOGICAL WORDS

Brood pouch
Marsupium
Incubation
Polygamous

QUESTIONS

1. What is parental care? Describe the parental care in Honey bee, Monkey, Kangaroo.
2. Describe the parental care in Mud wasp and Stickle back and Seahorse.

Animals in Relation to Man 19

The animal world is so diversified in structure and evolution that it is difficult to realise that there exists some sort of a relationship among the different animals. This relationship is evident in an animal's struggle for existence, which shows that the one, which can adapt itself to changing environment, over comes hazards and extracts the maximum out of the available resources, would survive and pass on its traits to its successors. Therefore, like any other organism, man is intimately connected with the surroundings in which he lives. On the one hand, he is adversely affected by the disease-forming harmful or parasitic animals, on the other hand, there are many useful animals which give him the necessary food for his very existence and also products which are of economic importance to him. Apart from these two types of useful and harmful animals, there are also some passive individuals which are indifferent to, and unconscious of, man's existence. They play no part in the life activities of man.

HARMFUL ANIMALS

There is a large number of animals which are carnivorous and harmful to man, such as the tiger, lion, leopard. They prey not only upon cattle but also on human flesh. There are some others, like some of the snakes, which are harmful to man in so far as they take many lives by their stings through which they inject deadly poison into man.

There are many more parasitic individuals which get into the human body directly or indirectly, and make man's life miserable by creating dreadful diseases in him. However, we shall concentrate only on the following few types of animals to see how they adversely affect the existence of man.

Entamoeba histolytica. This is one of the protozoans living in the intestines of man. It causes dysentery as a result of which, along with the stools (*i. e.* faeces) bits of the mucous membrane and blood are passed to the outside. This leads to serious complications and at times proves fatal. Dysentery caused by this amoeba is known as *amoebic dysentery*. Once the amoebae establish themselves in the intestines, it is difficult to get rid off them completely because they produce encysted spores, which are resistant to drugs.

Housefly. The housefly is a dreadful insect which is an agent for the spread of such diseases (Fig. 191) as typhoid, cholera and dysentery. They feed on decaying organic matter. The body of the fly is covered with numerous tiny hairs. It is provided with efficient licking and sucking mouth part in the form of a tubular proboscis.

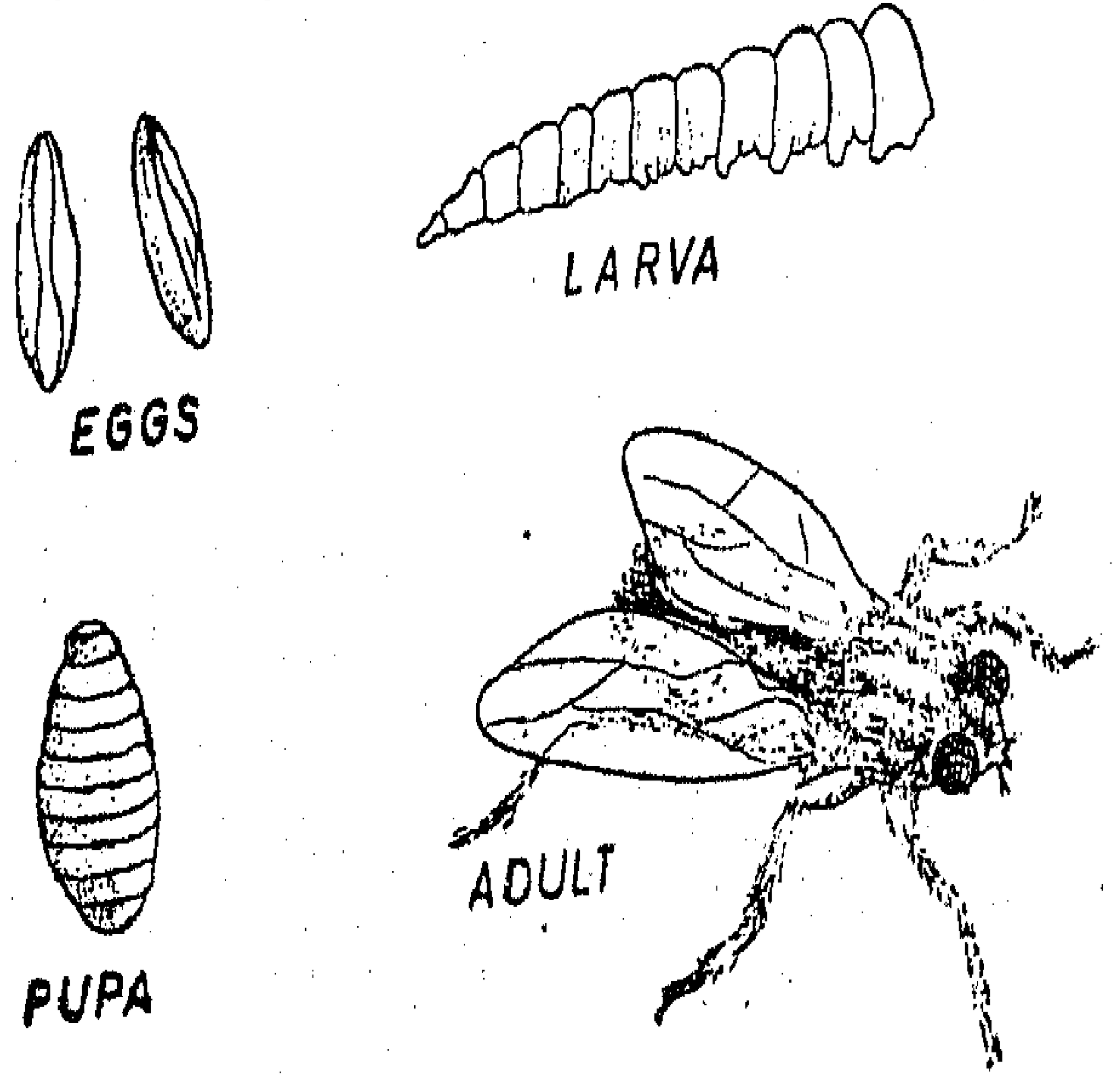


Fig. 191. *House fly : Life history*

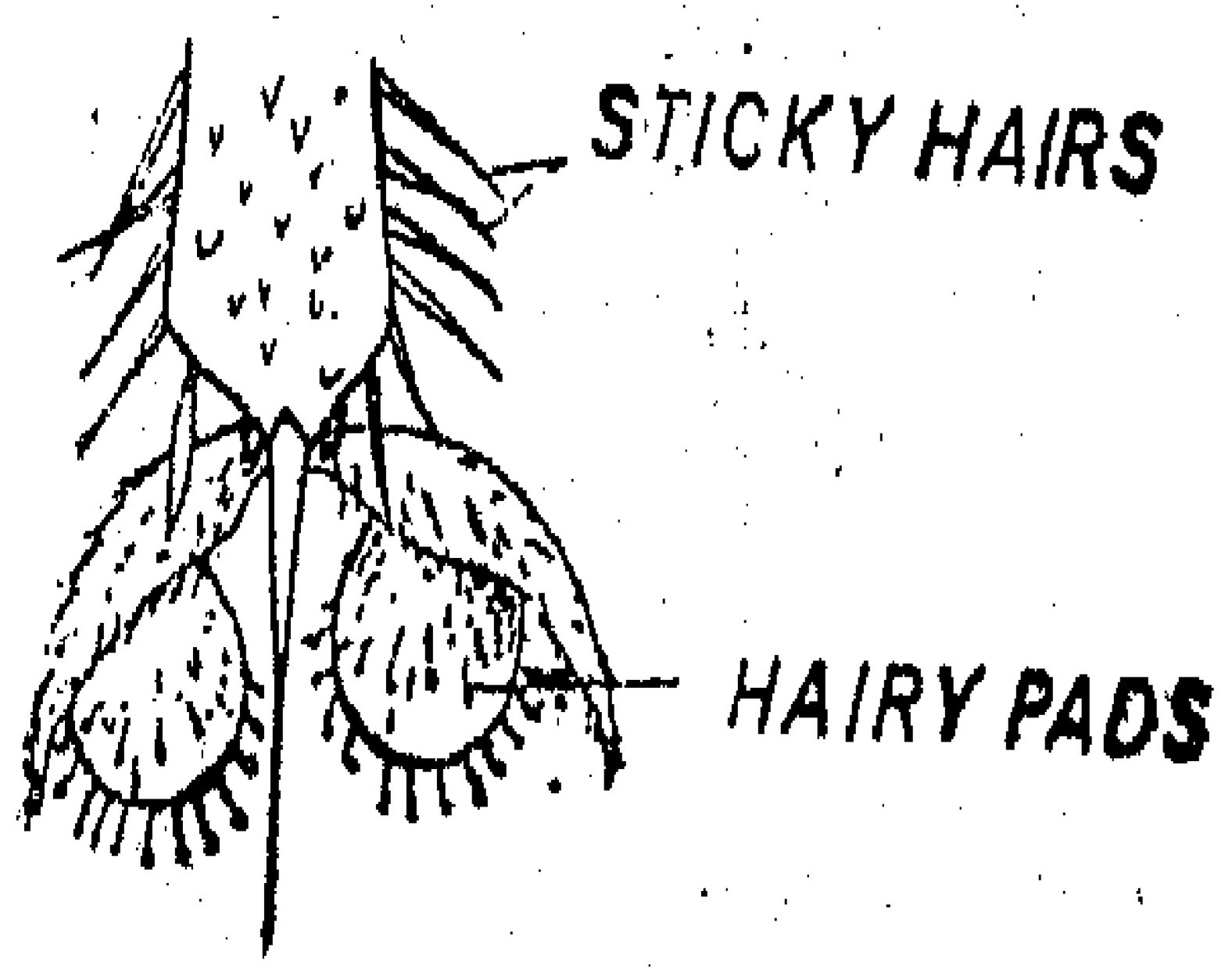


Fig. 192. *House fly : Leg*

The housefly easily picks up disease forming germs through its proboscis or by its hairy legs (Fig. 192) from the filth and excretory matter on which they alight for feeding or breeding. When the very same flies sit on exposed food, thee germs are transferred into healthy human beings. Houseflies, therefore, are the carriers of the diseases mentioned above.

Houseflies can be kept under control by avoiding the accumulation of any debris round about the premises and observing the necessary sanitary rules. Insecticides like D.D.T., Phenol, Phyrethrum etc., are used to eradicate the flies. Keeping them under control is the best way of preventing the incidence of disease.

Mosquito. It is another harmful insect, since it is a carrier of such diseases as Malaria and Elephantiasis.

It is the female mosquito which sucks the human blood by its piercing and sucking mouth parts, the proboscis. The female mosquitoes, therefore, are the carriers of germs in infected blood, which they transmit to healthy people.

The Anopheles (female mosquito), along with the blood sucked from the body of the victim of malaria, draws these parasites at certain stages of the development. The parasites undergo a series of changes in the body of the mosquito and ultimately come to be lodged in its salivary glands. Since the mosquitoes always pour some salivary secretion before they pierce the human skin to suck blood, the parasites are injected into man's body, where they grow at the cost of R. B. Cs. After certain stages of development, they burst the R. B. Cs in which they live, not only destroying the R. B. Cs but also, at the same time, liberating some toxins into the blood. It is this liberation of toxins which brings about high fever accompanied by the shivering known as *malarial fever*. This occasional destruction of R. B. Cs causes anaemia and general weakness. There are a few different kinds of malarial parasites. In one such type (Plasmodium vivax), the fever comes once in 48 hours, as the cycle of destruction of the R. B. Cs occurs one in 48 hours.

Mosquitoes can easily be prevented from multiplying by filling up the ditches and ponds of stagnant water, the breeding place of mosquitoes, and by also using various types of insecticides like kerosene, D. D. T., etc.

Round worms (Ascaris). They are parasites in the intestines of human beings, particularly in children. They are about 10 inches in length and have an anterior end with a mouth surrounded by lips which are quite suited for their feeding habits. These lay a large number of eggs resistant to digestive juices.

These are passed to the outside along with the fæces. They get into the human body through contaminated foods. In man, they go through a series of stages of their life history. During this period of development, they pass through the heart, lungs, trachea, oesophagus and stomach, and finally reach the intestines as adults. When they are in the respiratory system, they give rise to bronchial irritation, which results in coughing. Infection by Ascaris may lead to general debility.

Useful Animals

Honey-bees. Honey-bees are the most useful social insects. They have a regulated pattern of life. They have organised colonies, where there is division of labour. These bees are of great economic importance to man, in so far as they not only pollinate the varieties of flowers, thus bringing about a bigger yield of fruits, but also yield large quantities of high-energy food, the honey. The wax of a bee's comb is also of commercial importance to man. Honey is formed from the nectar collected from flowers by bees. This nectar, after being mixed with the saliva in their crop, gets reduced, and is converted into simple fruit sugar. This is stored in considerable quantities in the honeycombs which are built from waxy secretions on trees, and parts of buildings or rocks. Here it gets concentrated and forms the honey.

In the social structure of honey-bees, each colony has a queen, whose only concern is to lay eggs. There are workers, which are sterile females doing all the labour for the benefit of the colony; and there are the males or drones, whose business is to mate with the queen.

The workers build the honey-combs from the wax secreted by the glands present on their under surface. They feed and rear the young ones and store the honey. The queen deposits the eggs in hexagonal wax chamber, and the workers pour the fruit sugar, converted from nector, into the cells and seal them with wax lids.

The rearing of honey-bees for the production of honey and wax is known by them as *Apiculture* (Apis-*Honey-bee*).

Silk Worm. It is the larval stage of a moth known as silk moth, *i. e.*, Bombax mori. (Fig. 193.) It is of great commercial importance to man because the silk produced by them is used in the manufacture of clothes. The industry of rearing these worms for the production of silk is known as *sericulture*.

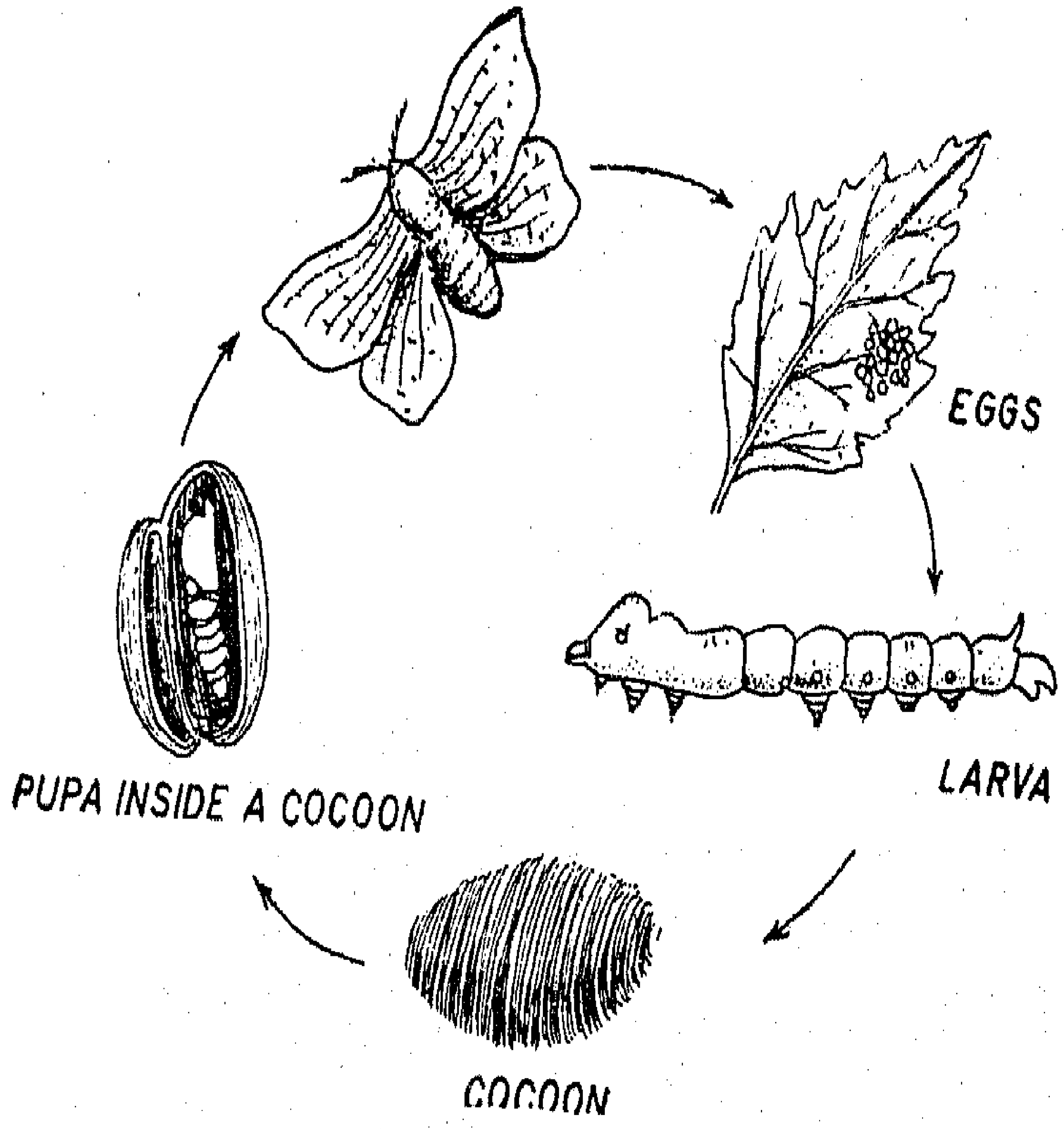


Fig. 193. *Silkworm : Life history*

The silk-worm (female) moth lays as many as 330 to 400 eggs on the leaves of the mulberry tree. These in due time (about 2 weeks) are hatched into the larvae known as caterpillars. They devour the mulberry leaves voraciously. The larva is an elongated, worm-like, segmented creature. After a few weeks of growth and moulting, or shedding its skin about four times, it begins to weave around itself a cocoon or pupal case. The cocoon is formed by the secretion coming through its mouth. This secretion, on contact with air, gets hardened to form a fine thread of silk. With this thread, the worm weaves around itself a cocoon. Then it undergoes further development within, till an adult moth comes out of the cocoon in about 2 weeks after breaking the cocoon. Obviously, if the moth is allowed to emerge, it break all the threads of the cocoon, and then the silk is of no use. Therefore, to get the silk intact. the animal is killed by putting the cocoon into boiling water, where the silk thread gets separated. This is spun out from the cocoon. From each cocoon, a thread, as long as about 1,000 feet, is obtained.

Domesticated animals. Man has domesticated a number of animals for his personal gains. These animals, once wild, have served him faithfully since time immemorial. Man in return has not been unkind, for he has given them food, shelter and affection. The most common animals that are put by man to serve him are cat, dog, horse, etc. Other animals, like the cow, buffalo, sheep and yak, have served humanity with precious food called milk, from which butter and cheese are obtained. Some of the animals such as pig, sheep and cattle, have been a source of meat for the non-vegetarians. The skin of many is processed so as to give leather. Many birds, such as fowl dcks and turkeys, yield food for man in the from of meat and eggs.

SUMMARY

1. Some animals are suseful to man while others are harmful.
2. The various harmful organisms and animals are (a) Entamoeba (b) Housefly (c) Mosquito and (d) Round-worms.
3. Useful animals are honey bees. Silk Worms, and domisticated animals.
4. Entamoeba causes amoeboid dysentry while the house fly carries germs and causes such as typhoid cholera, dysentry ete.
5. Mosquitoes are carriers of diseases such as malaria and elephantiasis.
6. Round-worms are parasites in the intestine of human beings. It may cause nausea, and vomiting in infected persons.
7. The honey bee produces honey which is not only a food but of medicinal importance.
8. Silk Worm produces silk which is of commercial importence.

BIOLOGICAL WORDS

Entamoeba histolytica
Dysentry
Elephantiasis
Ascaris

Organic Evolution

20

Our universe has been in existence for thousands of millions of years. The mother earth, when it was born (about 4,800,000,000 years ago), was not at all suitable for any life, for it was a very hot molten mass, revolving in the vast space, around itself and around the Sun. Many more millions of years had to roll by before the temperature, moisture and other conditions became suitable for the appearance of life. It is estimated that life originated some 1,500,000,000 (fifteen hundred million) years ago. It began in a very humble, simple way in the oceans. Since then, there has been no break in the record of life. It has been growing, it is growing, and it will continue to grow indefinitely in the future, unless, of course, human *atomic* folly destroys this *greatest show on earth.*

From this simple life, gradually and slowly, developed the present-day complex living organisms which inhabit the earth. This is *organic evolution*, which is a continuous but gradual and orderly process of progressive developmental changes towards a complex life from a simpler one. Accordingly, the existing organisms (plants and animals) are the modified descendants of other species that lived in the earlier times. Organic evolution is in short *descent with modifications.* It is so slow a process that it is measured in geological time.

The fact of evolution is now firmly and indisputably established by several bits of evidence, direct and indirect. But, in the earlier days of human civilisation, due to a lack of scientific knowledge, some other concepts were prevalent regarding the origin of life.

According to the *Theory of Spontaneous Origin*, life arises *de novo* from any non-living inorganic materials. This theory was dealt a blow by the genius of *Pasteur*.

The Christian Church preached yet another theory, the *Theory of Special Creation*, according to which all the living organisms were produced simultaneously in the remote past by a supernatural power. According to this theory, the present day organisms have remained unchanged since their origin, and will continue to remain unchanged in the endless future.

Now, although the Theory of Evolution has become an unchallenged fact of evolution, there are still differences of opinion regarding the *methods* or *processes* by which evolution has taken place. A few methods of evolution have been propounded by many great biologists; these are based on their own factual evidence and hypotheses. Here are a few outstanding theories:

I. Lamarck's *Theory of Inheritance of Acquired Characters*, based on the Use and Disuse principle.

II. Darwin's *Theory of Natural Selection*. This theory postulates that the prodigality in the production (*e.g.*, rapid multiplication) of organisms, leading to competition or *struggle for existence*, results in the production of new species.

Evidence in support of evolution has been furnished by different sources, namely, (i) Palaeontology; (ii) Comparative anatomy; (iii) Classification; (iv) Connecting links; (v) Physiology; and (vi) Embryology.

I. Palaeontological or Fossil Evidence

Fossils are either the remains of previously existing organism or indication of their presence. (Fig. 194). . These are found in the rocks which are stratified. The different strata of rocks represent different geological times, the lowest strata being the most ancient and the uppermost the most recent. The lowest strata contain fossils of very simple life (such as algae and lower invertebrates), while those of the middle strata are of the more complex organisms (such as mosses, ferns, gymnosperms, higher invertebrates and lower vertebrates). The recent strata show the predominance of spermatophytes and mammals.

This can only be explained by a series of progressive changes *i.e.*, organic evolution.

II. Evidence from Comparative Anatomy

This is an indirect evidence. If all the species of organisms had been separately created, they would then have tended to be infinitely varied in structure and to have no consistency in the pattern and functions of their organs. Yet we find that many rather unrelated, dissimilar organisms have organs and systems of similar functions.

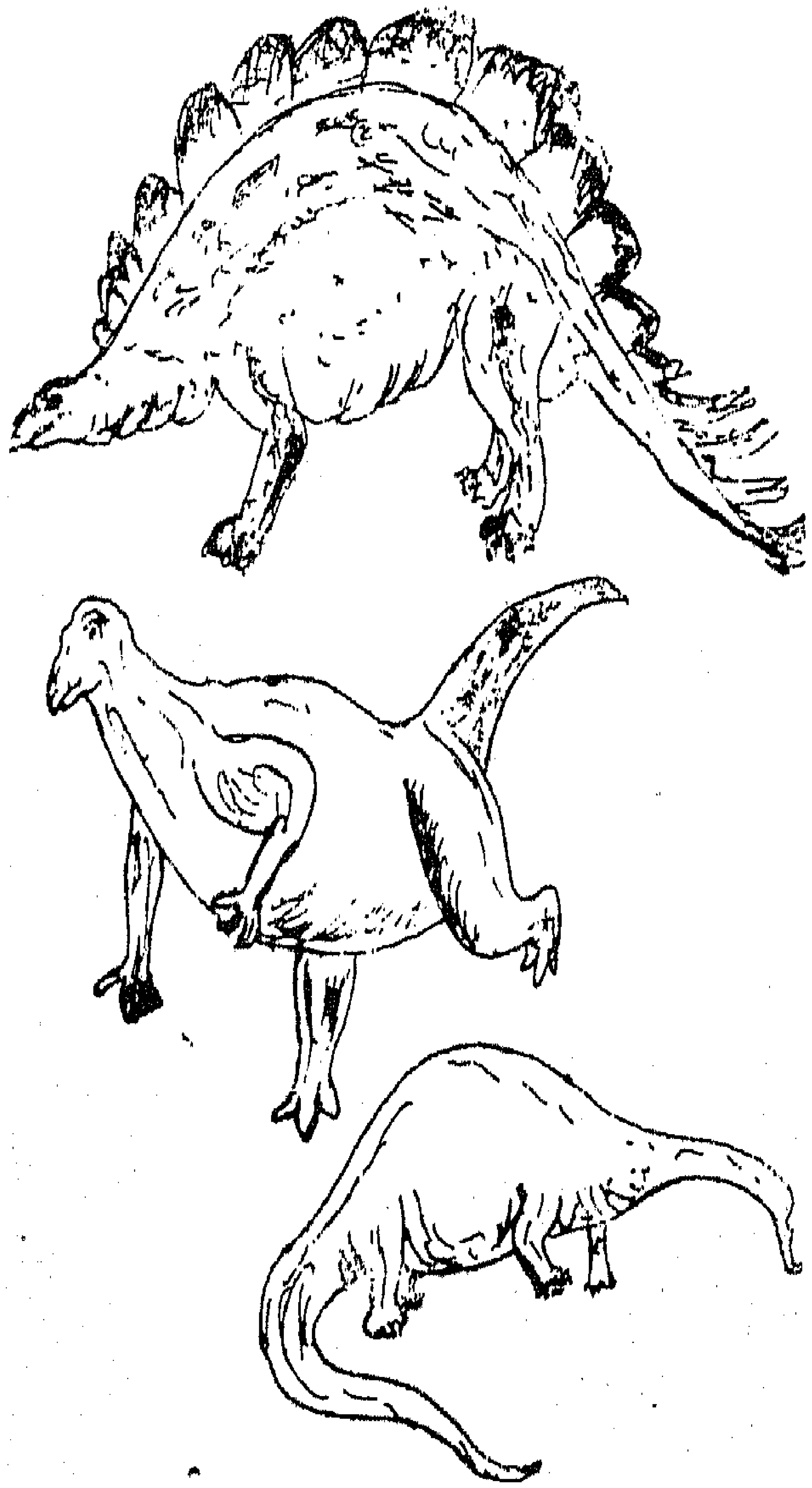


Fig. 194. *Some Extinct Reptiles*

This evidence can be studied under two heads: (1) Homology and (2) Vestigial organs.

(1) **Homology.** Analogous organs show a superficial similarity in structure and function; *e.g.*, the wing of an insect and that of a bird. Homology is the fundamental similarity in structure, irres-

pective of shape and function, because of similarity in embryonic origin.

Examples of homologous organs are the vertebrate limbs (Fig. 195), such as hand of a man, flipper of a seal, wing of a bird and wing of a bat. Though they are adapted for different modes of locomotion, they have still retained the similarity in their skeletal structure, namely, the presence of humerus, radius-ulna, carpals and metacarpals. This similarity can be explained only through common ancestry, which is the central theme of organic evolution.

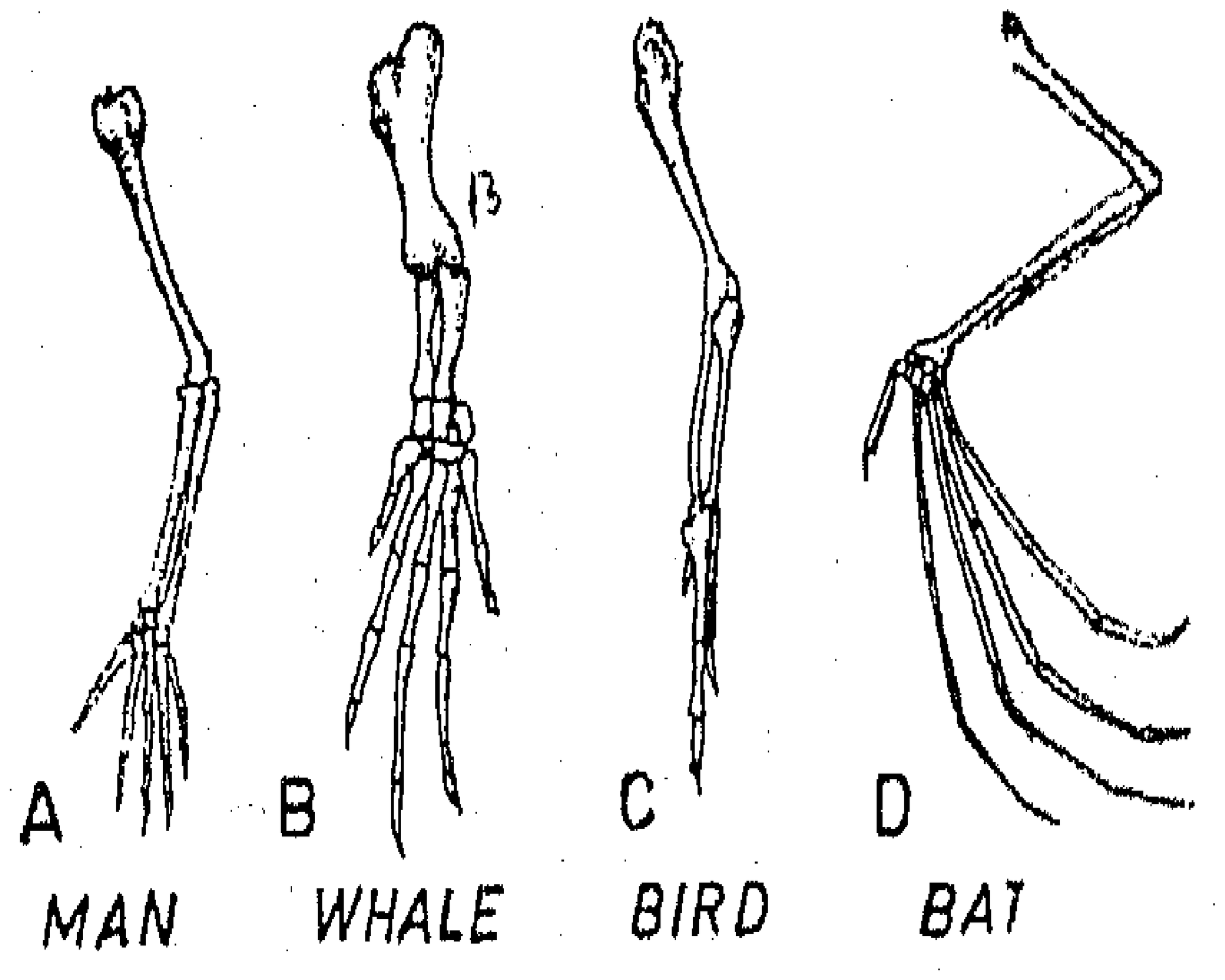


Fig. 195. *Homology of Vertebrate limbs*

(2) **Vestigial organs.** These are the non-functional or defunct organs in some individuals. They are thus the reduced structures which in other organisms are well developed, being functional.

Such vestigial structures are found in various animals. The reduced splint bones of the living horse are the vestiges of the well-developed toes of the ancestral horse. The presence of the reduced wing skeleton in the flightless kiwi in spite of the absence of wings; the presence of claws representing hind-limbs in the python; the presence of the pelvic girdle bones in the whale in spite of the absence of hind-limbs; the presence of reduced eyes in cave-dwellers whose related forms, living out in the open, have well developed eyes—all these and several other are examples of vestigial organs. The human being harbours several such structures (Fig. 196), *viz.*, the appendix, the third eye-lid in the corner of the eye, the reduced ear musles, the coccyx (tail bone), etc.

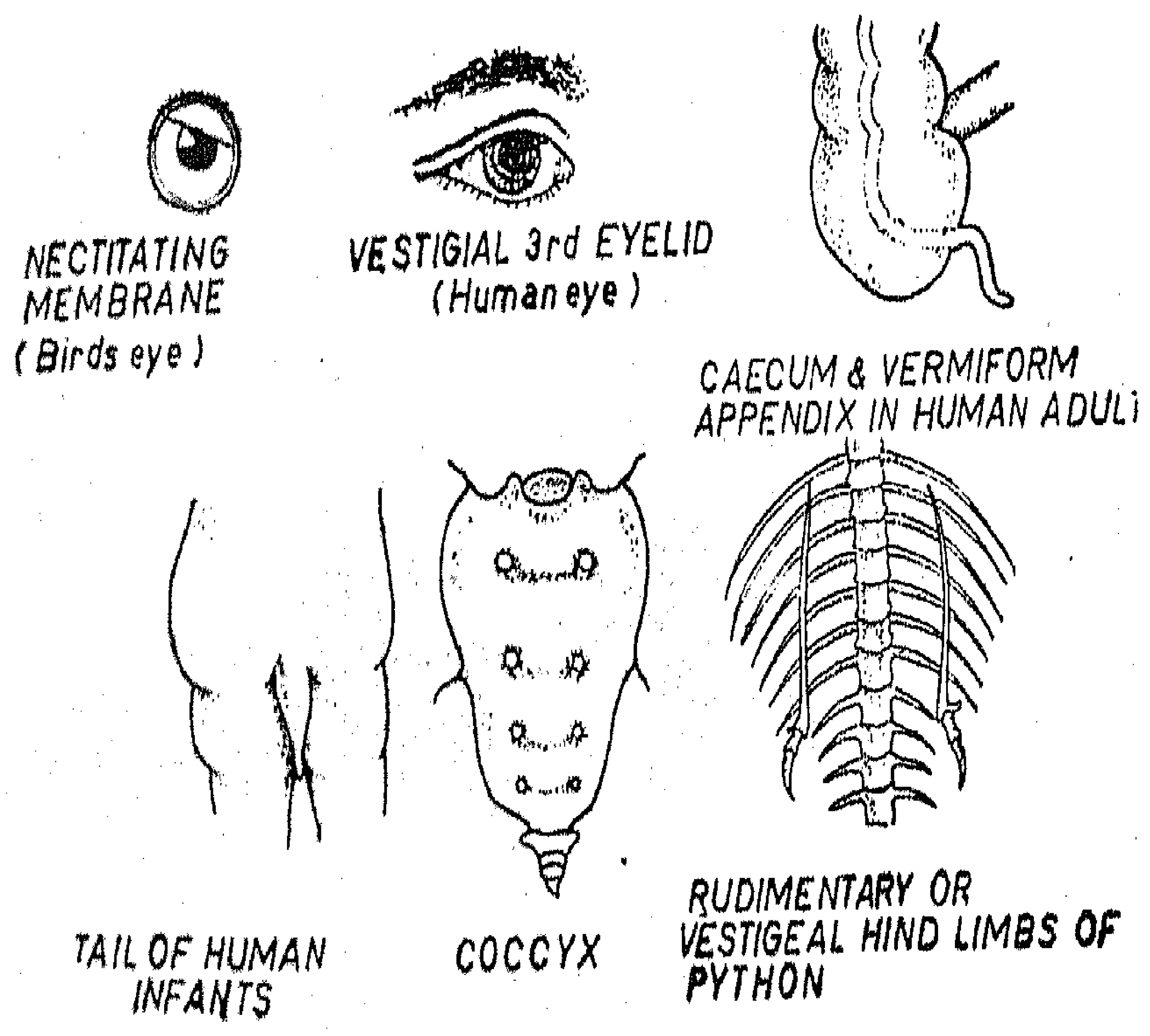

NECTITATING MEMBRANE (Birds eye)
VESTIGIAL 3rd EYELID (Human eye)
CAECUM & VERMIFORM APPENDIX IN HUMAN ADUL
TAIL OF HUMAN INFANTS
COCCYX
RUDIMENTARY OR VESTIGEAL HIND LIMBS OF PYTHON

Fig. 196. *Vestigial organs*

The presence of these structures is very difficult to explain by any other theory, but they are easily resolved from the standpoint of organic evolution. These structures, which are inherited from ancestors among whom they were functional and well developed, are now in the process of disappearing from their living descendants.

III. Classification

It is a method of grouping diverse organisms in an orderly arrangement and in a definite gradation. Classification attempts to show the inter-relationships between divergent groups of organisms. One can arrange animals in a series of complexity, starting with the acellular protozoa, through multicellular, diploblastic Coelenterata, tripoblastic, accelomate, Platyhelminthes triploblastic coelomate Annelida, Arthropoda, Mollusca and Echinodermata, and then gradually passing to the Chordata.

IV. Connecting Links

They provide a very conclusive evidence in support of evolution. We have seen that different groups (Phyla) are related to each other. The connecting links are the intermediate organisms which, by virtue of possession of the characteristics of both the groups, firmly establish the link between those groups.

Duck-billed Platypus (Fig. 197) is a mammal, as it has hair on the body and suckles its young ones on milk. Yet it retains several ancestral reptilian characteristics, such as laying eggs and presence of cloaca.

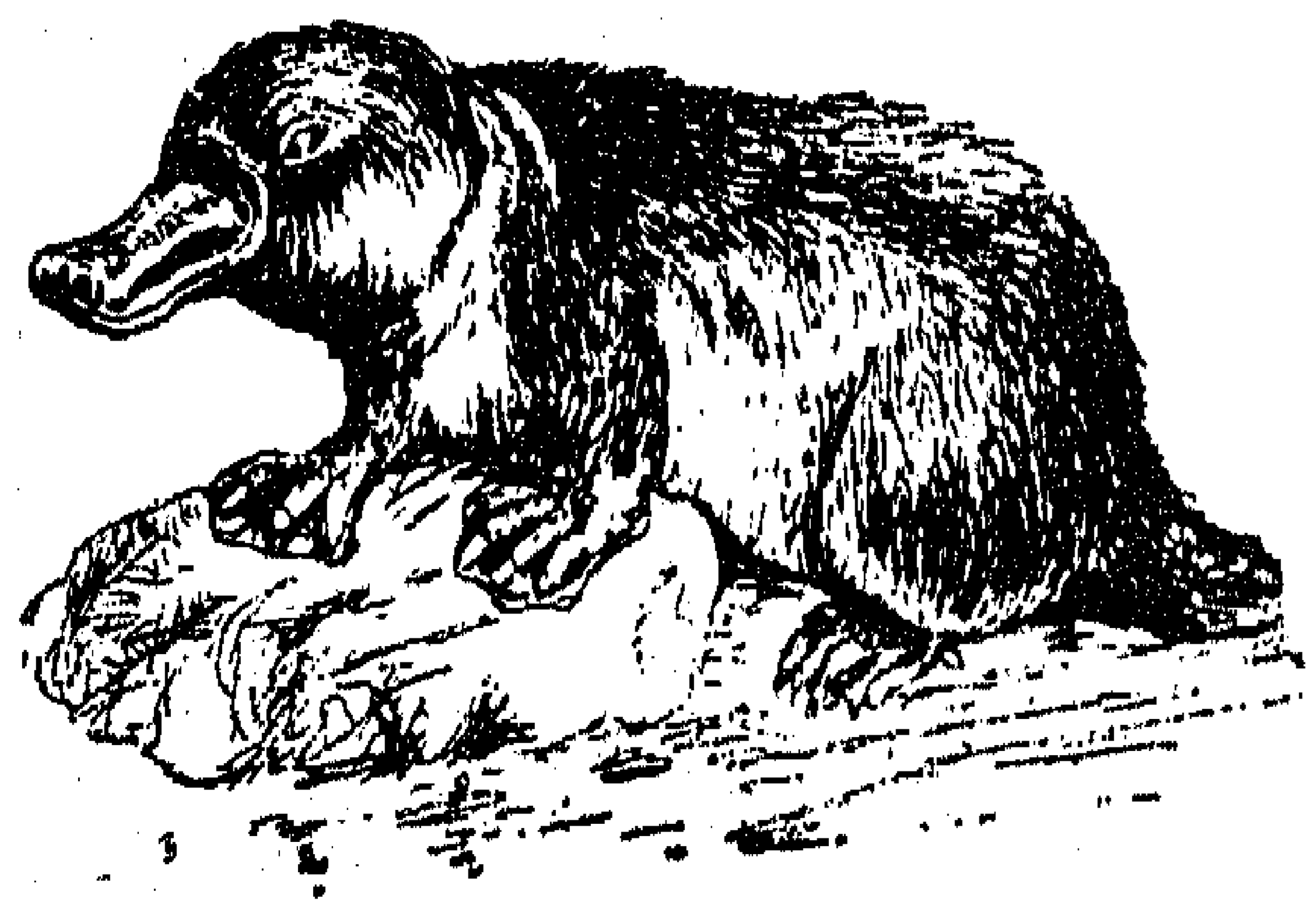


Fig. 197. *Platypus*

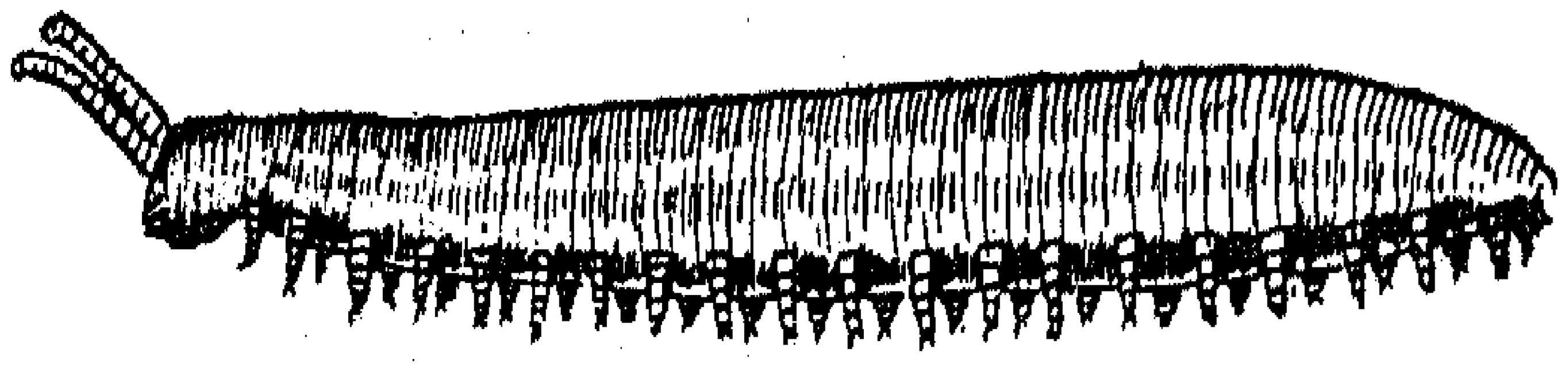
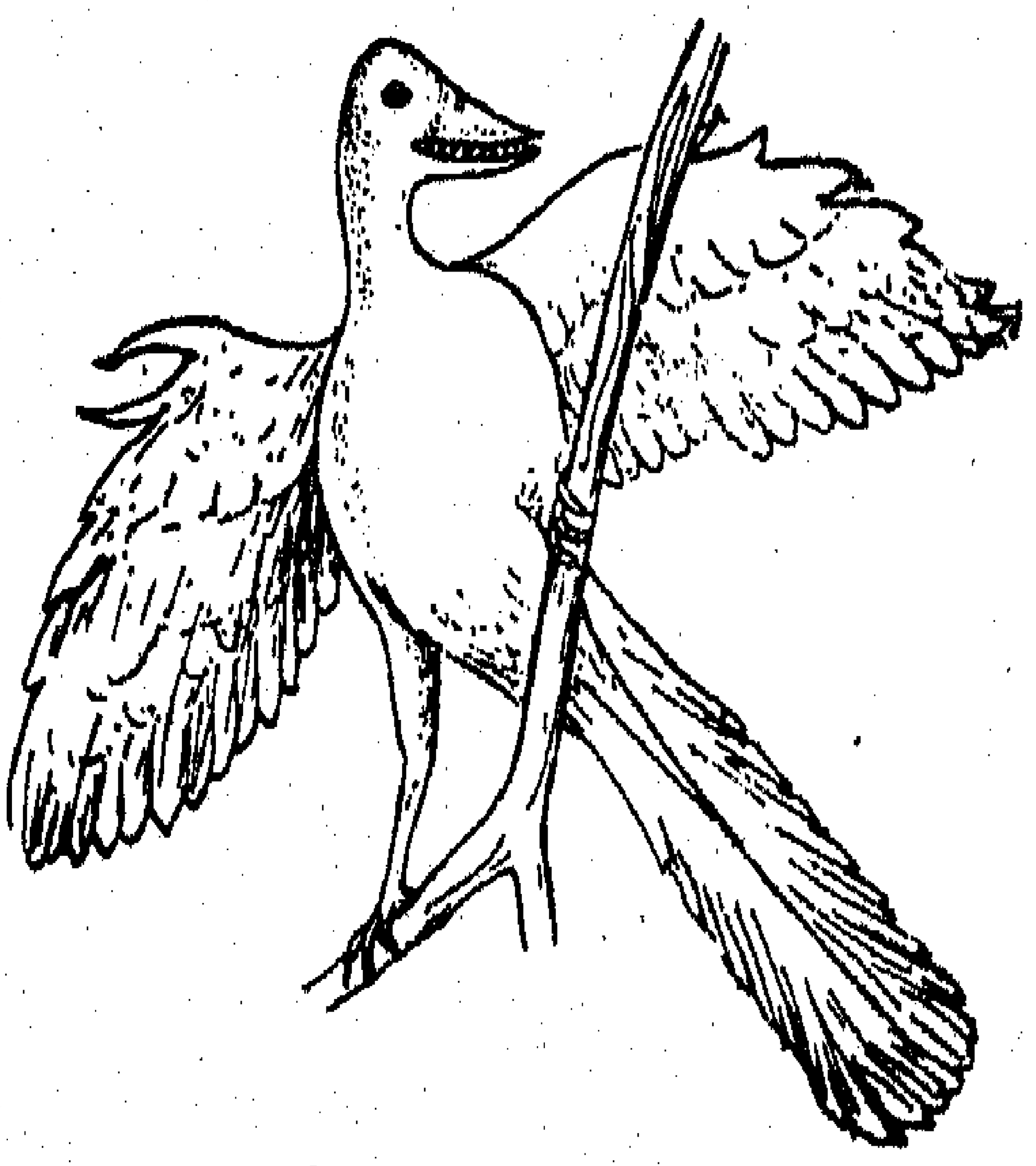


Fig. 198. *Peripatus*



199. *Archeopteryx*

The Peripatus (Fig. 198) is a classic example of the connecting link between Annelida and Arthropoda. It is an arthropoda with the haemocoele, and tracheae as respiratory organs; yet it has the annelidan characteristics of the non-chitinous, soft cuticle and segmentally arranged nephridia.

The Archeopteryx (Fig. 199) is a fossil bird which has several reptilian characteristics (such as teeth and tail). If its feathers had not been preserved, it would have certainly been classified as a reptile.

V. Evidences from Physiology

All organisms are characterised by three vital physiological activities, *viz.*, metabolism, irritability and reproduction. This cannot be an accident. This is possible only if we presume that all organisms have descended from the ancestral protoplasm with with such properties.

The close similarity between the blood of different vertebrates is shown by several chemical tests. Thus, the blood of a mammal is much more like that of any other mammal than it is like that of reptiles or aves. Similarly, serological tests indicate a greater kinship between man and chimpanzee or gorilla than between man and monkey.

The persistent similarity in the digestive enzymes of all animals and in the hormones of all vertebrates can be explained only through the fact of a common ancestry.

VI. Embryological Evidence

It is a well known fact that the earlier stages of development (*i.e.*, embryos) of different vertebrates (Fig. 200) show a greater resemblance than their adults. In fact, at times it is difficult to distinguish between them. All these embryos show the presence of fish-like gill-arches, which can be of use to aquatic groups like the Pisces and the Amphibia. But astonishingly, they are present in reptiles, birds and mammals, among whom the embryos are not at all aquatic, and hence gill-arches are of no use.

The presence of gill-slits in the embryos of reptiles, aves and mammals can be explained by the theory of evolution in that they

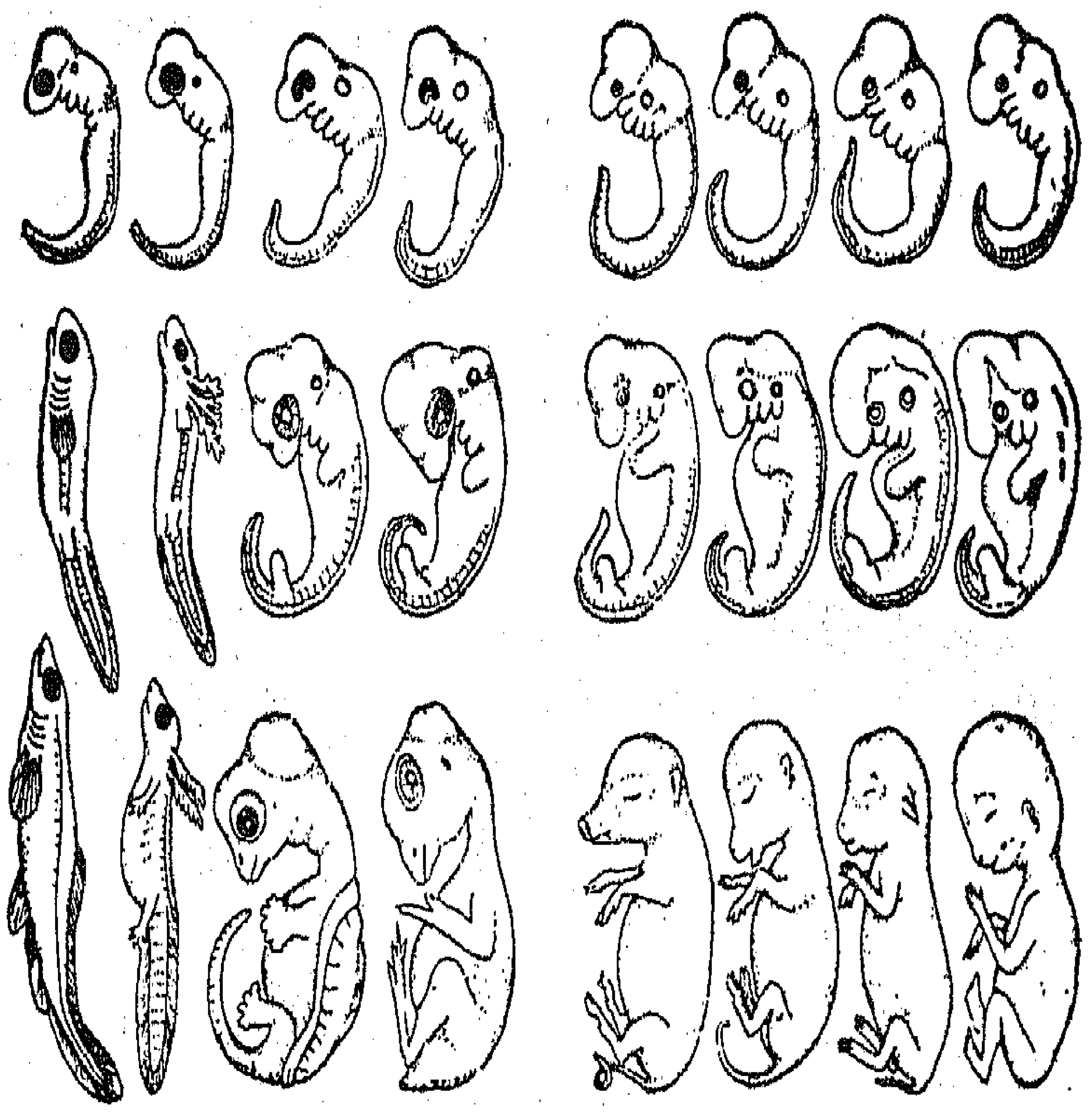


Fig. 200. *Embryos of different Vertebrates*

are the ancestral relics. It means that a more highly evolved organism has to pass through a number of structural stages which are present in the adults of lowly-evolved organisms. This embryonic repetition of the history of the race is known as the *theory of recapitulation*, which states that Ontogeny (development of the individual) repeats Phylogeny (development of the race).

Thus embryology can reveal inter-relationships of organism.

BIOLOGICAL WORDS

- Paleontology
- Vestigial
- Nictitating memdrane
- Coccyx
- Eohippus
- Natural selection.

QUESTIONS

1. What is organic evolution ? Describe any three evidences in support of it.
2. Describe Physiological Morphological & Embryological evidences in support of evolution.
3. Write short notes on:--
   (1) Fossil, (2) vestigeal organs (3) connecting links.

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